# Pre-Flood Warning System Based on User Mobility

by

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15278

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Technology (Hons)
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Information and Communication Technology Programme
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Approved by,

______________________

(Dr Izzatdin bin Abdul Aziz)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
May 2015

# CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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FATEEN ATIQAH BINTI MASTOR

# ABSTRACT

The occurrence of flood causes millions of Ringgit in damages, along with the loss of life and property, and the devastation of agricultural and livestock. Therefore, an effective pre-flood warning system must be developed to mitigate flood losses and lessen the flood effects. However, when developing a warning system for flood disaster, limited communication during the occurrence of floods and the availability of electricity supplies should be taken into account. Thus, this research project proposes a conceptual framework with three (3) main stages: monitor water level, alert flood victims on flood danger status and inform flood victims to relocate to the nearest relief center. A system architecture has been designed for this research project and a prototype system is developed. The prototype system is made up of a medium sized aquarium tank, a hand pump, HC-SR04 ultrasonic sensor, Arduino UNO R3 and IComsat GSM shield. To validate the proposed prototype system, an experiment with controlled water rising effect is conducted in a lab scale setup. The results prove that the proposed prototype system is reliable as it is able to measure water level accurately and broadcast warning SMS immediately to flood victims. Thus, by having an effective real time pre-flood warning system, immediate action can be carried out in order to save lives and minimize the damages caused by flood disaster.

# ACKNOWLEDGEMENT

In the name of Allah, The Most Gracious and Most Merciful

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Thank you.

# TABLE OF CONTENT

# LIST OF TABLES



# LIST OF FIGURES

# ABBREVIATIONS

| | |
|---|---|
| UTP | Universiti Teknologi PETRONAS |
| SIM Card | Subscriber Identity Module Card |
| GSM | Global System for Mobile Communication |
| MTSO | Mobile Telephone Switching Office |
| SMS | Short Messaging Services |
| IP | Internet Protocol |
| 2G | Second Generation |
| 3G | Third Generation |
| RxD | Receive Digital pin |
| TxD | Transmit Digital pin |
| KB | Kilobyte |
| Kbps | Kilobits per second |
| KHz | Kilohertz |
| cm | Centimetres |
| m | Metres |
| ms | Metres per second |
| mA | Milliamps |
| MHz | Megahertz |
| V | Volts |
| VDC | Volts Direct Current |
| USB | Universal Serial Bus |
| HDMI | High-Definition Multimedia Interface |
| DVI | Digital Visual Interface |
| SCART | Syndicat des Constructeurs d'Appareils Radiorécepteurs et Téléviseurs |
| AC | Alternating Current |
| DC | Direct Current |
| IDE | Integrated Development Environment |
| ISMSC | International Symposium on Mathematical Sciences and Computing |
| SEDEX 35 | 35rd Science and Engineering Design Exhibition |

# CHAPTER 1
# INTRODUCTION

## 1.1 Background

In Malaysia, floods occur nearly every year during the monsoon season and are considered as a regular natural disaster in the country. Given Malaysia's geographical location, we face a heavy and regular rainfall during the local tropical wet season from October to March each year and flood is a natural result of this cyclical monsoons [3]. When floods happen, they caused millions of Ringgit in damages, the loss of life and property along with agricultural and livestock devastation [4]. Furthermore, according to the Minister of Agriculture and Agro-Based Industry Datuk Seri Ismail Sabri Yaakob, the recent massive floods in Kelantan has resulted in about RM105 million losses where 11,099 hectares of agriculture land destroyed, affecting 6,309 farmers, breeders and fishermen [5].

At the end of 2014, due to the climate change that is followed by recurrent heavy rainfall, Sarawak and the Peninsular Malaysia have experienced 40% rainfall, which increased from 30% in the past. As mentioned in the Borneo Post by the environment scientist and also the Deputy Minister of Natural Resources and Environment, Datuk Seri Dr James Dawos, the sea level had increased by 22 cm as of the present-day due to global warming and the highest king tide was estimated at 6.3 meters [6]. When there is high tide, flooding will occur and thus, Dawos concluded that there is no stopping to floods and things could be worse if no implementation of long-term solution is taken to counter the problem.

Therefore, in order to mitigate flood losses and lessen the flood effects, it is important to come out with an early warning system [7]. Unfortunately, there is a lack of concern in the substantial of an early warning system even though the technologies are widely available. The system lacks the basic abilities such as equipment, skills and resources [1]. Warning might fail to reach the local authorities and sometimes, the warning may not be understood because of ineffective and unsuitable alert tools of communication channels are being used. Other causes could appear because of the inadequacies political commitment, weak coordination among the various actors and lacks of public awareness and public participation in the development and operation of early warning systems. Therefore, this research project aims to propose an architecture for a pre-flood warning system based on user mobility and hence to develop a prototype system for the proposed architecture.

## 1.2 Problem Statement

The occurrence of flood causes millions of Ringgit in damage, along with the loss of life and property and the devastation of agriculture and livestock. To have an early warning system that alerts communities on the increasing water level is practical, however, there are significant inadequacies that needs to be improved. The existing warning system lacks the basic abilities to monitor water level, to give immediate and real time warning notifications and to offer a well-organized coordination during evacuation process. When developing a warning system for flood disaster, limited communication during the occurrence and the availability of electricity supply should be taken into account. Therefore, there is a need to develop an early warning system that overcomes the lacks of the existing system to mitigate flood losses and lessen the flood effects in dire conditions.

## 1.3 Objectives

1. To perform a comparative study of flood disaster in Malaysia and the existing pre-flood warning systems.
2. To develop a prototype system for the proposed pre-flood warning system.
3. To validate the proposed prototype system through experimentation.

## 1.4 Scope of Work

In the real world implementation, the proposed system will be using an HC-SR04 ultrasonic sensor that is installed at a riverbank to measure water level. The sensor is connected to an Arduino UNO R3 microcontroller that will then process the collected data before sending them to IComsat GSM shield. The GSM shield acts as a medium to send warning messages from the microcontroller. However, as proof of concept, the project is scaled down to only lab scale setup and experimentation. The proposed prototype, which consists of HC-SR04 ultrasonic sensor, Arduino UNO R3 microcontroller and IComsat GSM shield, is tested in a lab scale aquarium tank with controlled water rising effect. The GSM shield will be connected to the nearest base station and SMS notification is sent only to the cellular users that are logged within the flood affected based station. These logged numbers include residents, local authorities and passersby. This can be done by requesting the dynamic list of cellular users from the Mobile Telephone Switching Office (MTSO) as the MTSO maintains records of users' mobility changing between base stations in specific geographical area [8]. To save operational cost and ensure reliability of the system during power outage, solar cell is used to ensure the system works when there is no electricity supply to power up the sensors at the affected sites.

# CHAPTER 2
# LITERATURE REVIEW

It is addressed in Chapter 1 that this research project focuses on performing a small-scale study of flood disaster and the existing flood warning system. The significance of performing the study is to find the suitable method that allows a system to detect water level accurately and give early warning to communities and local authorities to prepare for relocation to the nearest evacuation centre using SMS. Thus, Chapter 2 discusses on how this project is related to the work of others and what can be improved based on the identified gaps and discrepancies in the literature.

## 2.1 Flood Disaster in Kelantan, Terengganu, Pahang, Perak and Johor

There is no ending to flood disaster in Malaysia due to the monsoon rainy season and flashflood. In the Malaysian history, one of the worst floods that happened in decades is the most recent massive flooding caused by the monsoonal rain. They are the floods that hit the country from 15 December 2014 till 3 January 2015 and resulted in a total of 210,116 victims in Kelantan, Terengganu, Pahang, Perak and Johor were relocated to safety [6].

Based on the news reported in The Star Online, the north-eastern state of Kelantan recorded the worst hit with the number of people displaced making up to 70% of the total, followed by Terengganu and Pahang at 14.9% and 11.5%. During the flood occurrence, the communications have become even more challenging as access by road is limited due to waters that submerged many of the main roads, until at one point, the electricity supply had to be cut off to ensure the victims do not get electrocuted [5].

Referring to the news of flood disaster in Malaysia, particularly in Kelantan, Terengganu, Pahang, Perak and Johor, it is obvious that something needs to be done in order to prepare for the catastrophic flooding. Therefore, there is a need to improve the existing flood forecasting and warning system to become more efficient in order to mitigate flood losses and lessen the devastation of property and lives [9]. Thus, it is essential to have an early warning system that notifies the residents, passersby and local authorities within the affected area on the rising water level status for them to take safety precautions and for the local authorities to prepare for a smooth evacuation process of flood victims to the nearest relief centre.

## 2.2 Related Work

This section discusses on how this research project is related to the work of others and what can be improved based on the identified gaps in the literature.

### 2.2.1 Automated Photonics Flood Warning System (Flood-SMS)

Flood-SMS is a life saving flood warning system that alerts people through Short Message System (SMS) once the water level nearby starts to rise. The investor of the system, Prof. Dr Abu Bakar Muhammad said that the system is designed to measure three (3) levels of flood warning namely flood occurrence, flood alert and flood at dangerous level. All these warning signals are sent in the form of SMS through a GSM modem to subscribers. The system is operated using batteries to ensure it is free from any electrical shocks arising from short circuits [10].

Besides that, Flood-SMS utilizes photonics sensors to detect all the three levels of flood (i.e. occurrence, alert and dangerous) and triggers the microcontroller to relay the appropriate SMS through the GSM modem. In Flood-SMS, optical fiber is used to detect the rise of water level as it is also known for a fact that fiber optic system can withstand any electrical shocks. The fiber also enables the signal to travel as far as 2 kilometres, allowing the electronic circuitry to be placed high above the floodwater [10].

### 2.2.2 Cooperative Flood Detection using GSMD via SMS

This project focuses on detecting water level remotely using wireless sensor network when flood disaster happen. Programming language such as Visual Basic and C# is used to implement the software with the ability to control, sense and perform the measurement of water level. Ozeki Message Server-6 is used as the SMS gateway application that sends warning SMS from the web application direct to the victims through their mobile phone [1].

## 2.3 Gaps Found in the Literature and Way Forward

Although it was clearly shown that Flood-SMS and the cooperative flood detection using GSMD via SMS are both beneficial as an early warning system, it is nevertheless inefficient due to the fact that they are sending the warning SMS only to subscribed users and both system did not clearly state the location of the nearest evacuation centre for the victims to go immediately after receiving the SMS. Therefore, the development of the proposed system in this research project aims to broadcast warning SMS to all residents, passersby and local authorities that happen to be within the affected area with regards to their mobility. This can be done by utilizing the information recorded by the MTSO that controls the base station. The information contains the location of logged users in a specific geographical area, thus introducing a more efficient and hassle-free pre-flood warning system.

## 2.4 Communication Channels used in Disaster Warning

In this project, short messages services (SMS) plays an important role for broadcasting messages simultaneously to multiple users. SMS is a service available on most digital mobile phones that permits the sending of short messages between mobile phones, other handheld devices and even landline telephones. Based on the comparison in Table 1, SMS has the most advantage to be used as a communication channel in disaster warning because information can be broadcasted simultaneously to multiple users in a short time.

This suits the second need of this proposed project, where immediate warning notifications on the water level status are required to be given to the residents, local authorities and passersby to give them ample time to take immediate action.

TABLE 1. Comparison between Communication Channels used in Disaster Warning [1]

| Channel | Advantage | Disadvantage |
|---|---|---|
| Electronic Sirens | Capable of reproducing warning signals and voice announcements. | Power failures always occur during emergencies. Cannot disseminate detailed message. |
| Radio and Television | Widespread. | Take time to get warnings. |
| Telephone (Fixed and Mobile) | Messages can be delivered quickly. | Authenticity issues. Does not reach non-users. Network congestion. |
| SMS | Information can be broadcasted simultaneously. | Does not reach non-users. Network congestion. |
| Internet or Email | Interactive multiple sources can be checked for accuracy of information. | Not widespread. |
| Amateur or Community Radio | Excellent for rural, poor and remote communities. | Not widespread. |

Moreover, in the United States, SMS notification is proven to help save lives during tornados that happen in the months of April, May and June. A testimonial article reported that one of the victims of tornados disaster mentioned that he lives in an area where tornado sirens cannot be heard, therefore text alerts was the only mode of communication that has helped him to seek for shelter immediately [11]. As a conclusion, SMS will be used in this project as the main communication channel to broadcast alert that notifies users on the occurence of flood disaster and at the same time act as a warning system that informs users on the water level danger status.

### 2.5 Comparative Study on Application of 2G-GSM and 3G for SMS Technology

Table 2 shows the comparative study between 2G-GSM and 3G technology.

TABLE 2. Comparative Study on 2G-GSM and 3G Technology

| Area of Difference | 2G-GSM | 3G |
|---|---|---|
| Definition | Global System for Mobile communication as an open digital cellular technology to transmit mobile voice and data services [12]. | The third generation of telecommunication hardware standards and general technology for mobile networking [13]. |
| Number of Subscribers | Over 3 billion people across more than 212 countries and territories. | 1,750.3 million. |
| Data Transfer Rate | 9.6 kbps. | Up to 14.4 Mbps on the downlink and 5.8 Mbps on the uplink. |
| Features | Digital voice service.<br>Advanced messaging.<br>Global roaming.<br>Circuit-switched data. | Always-on connectivity.<br>Global roaming.<br>IP-enabled. |
| Advantages | Ability to roam and switch carriers without switching phones [13].<br>Wider coverage in rural areas and major cities. | Offers much faster data transfer.<br>Offers powerful multimedia services and applications. |
| Disadvantages | Not suitable for web browsing andmultimedia applications.<br>Require longer time for download activity. | Expensive but limited.<br>Some area does not have 3G coverage especially rural areas. |

Based on the comparative study in Table 2, 2G-GSM has the most advantage compared to 3G as it has wider coverage in rural areas and major cities. Moreover, GSM technology is needed to allow messages to be broadcasted and delivered to the receivers in a short time so that immediate action will be taken right away. Thus, the GSM technology is chosen as a medium to broadcast warning SMS simultaneously to multiple users from the IComsat GSM shield after receiving instructions from the microcontroller.

### 2.6 User Mobility

Cellular network is divided into many cells and each cells has a base station to provide signal coverage. This base station detects the mobile users cellphone numbers while the users are logged in the cell and these numbers are stored in the Mobile Telephone Switching Office (MTSO) database. User moves from one cell to another cells. Therefore, when user moves to another cell, the user's cellphone number in the previous cell is removed and logged into the new cell. Thus, by leveraging on this system, we can trace the presence of mobile users in a cell and actively alerts users via SMS notification when they are in the flood affected area. Consequently, only users who happen to be within the area of flood disaster will be notified to evacuate the area immediately.

### 2.7 Ways to Measure Water Level

Table 3 shows a comparative study between ultrasonic sensor and water level sensor. Ultrasonic sensor provides precise, non-contact distance measurements from about 2 cm to 400 cm and it emits a high frequency sound of 40 KHz. The principle of ultrasonic distance measurement is the same as radar and sonar and it is ideal to be used for level monitoring or linear motion monitoring applications [2]. Ultrasonic sensor is chosen to be installed at a riverbank to measure water level accurately as it can be triggered as fast as every 50 ms or 20 times per second.

TABLE 3. Comparative Study on Ultrasonic Sensor and Water Level Sensor to Measure Water Level

| Area of Difference | Ultrasonic Sensor | Water Level Sensor |
|---|---|---|
| Ranges | 0.33-3, 0.33-12,1-48 ft. | 0-3, 0-15, 0-30, 0-60, 0-120, 0-250, 0-500 ft. |
| Resolution | 0.009, 0.035, 0.141 inch. | Infinitesimal (Analog). |
| Accuracy | Better than 0.5% of range at constant temperature; affected by temperature gradients, target echo strength and speed of sound in vapors. | ±0.1% of full scale at constant temperature.<br>± 0.2% over 1.37°C to 21.1°C range. |
| Transducer Type | Ruggedized piezoelectric. | - |
| Update Rate | 50 ms or 20 times per second. | 125 ohms. |
| Output | 4-20 mA (4 mA is minimum water level and 20 mA is maximum water level). | 4-20 mA or 0.5 to 2.5 VDC. |

## 2.8 Microcontroller

As illustrated in the proposed system architecture in Chapter 5, Figure 11, a microcontroller is required to integrate the ultrasonic sensor with the GSM shield. The microcontroller will process the input data gathered from the ultrasonic sensor before it is passed as the output data to the GSM shield. The calibration between the ultrasonic sensor and the GSM shield is done by uploading instructions code to the microcontroller. Table 4 shows a comparison between Arduino UNO R3 and Raspberry Pi.

TABLE 4. Comparison between Arduino UNO R3 and Raspberry Pi

| Specifications | Arduino UNO R3 | Raspberry Pi |
|---|---|---|
| Processor | Atmel ATmega328 | 700 MHz ARM 11 |
| Chip | 16 MHz crystal oscillator | Broadcom BCM2835 |
| Flash Memory | 32 KB | - |
| Inputs | 6 analog | HDMI, DVI, Composite or SCART |
| Interface | 14 digital I/O pins | Broadcom Video Core IV |
| Operating Voltage | 5 V | 700 mA |
| SRAM | 2 KB | - |
| EEPROM | 1 KB | - |
| Clock Speed | 16 MHz | - |

Based on the comparison between Arduino UNO R3 and Raspberry Pi in Table 4, Arduino is chosen as the microcontroller in this research project. Arduino provides an ease of programming as it operates on ATmega328 that allows direct access and control to the programming of the microcontroller. In order to get started, it can be connected to a computer with a USB cable or it can be powered up with an AC-to-DC adapter or battery. The chip comes with crystal oscillator design to generate low frequency and phase jitter, which is recommended for USB operation [14].

### 2.9 Solar Cell

Sunlight is known as a clean and renewable energy source that can be converted into a usable energy by solar cells. Solar energy is chosen to supply power for the pre-flood warning system to ensure that the system works even though when there is no electricity supply during the occurrence of flooding. Moreover, with the use of solar energy, large amount of money can be saved and it keeps our climate livable as it causes no pollution and makes no noise.

# CHAPTER 3
# METHODOLOGY

In this chapter, the research method carried out throughout this project will be explained. As illustrated in Figure 1, the applied method involves a process that comprises of seven (7) phases that begins with observation, problem definition, conceptual framework, completion of literature, comparative study between existing technologies, system architecture design, prototype development and ends with prototype testing.

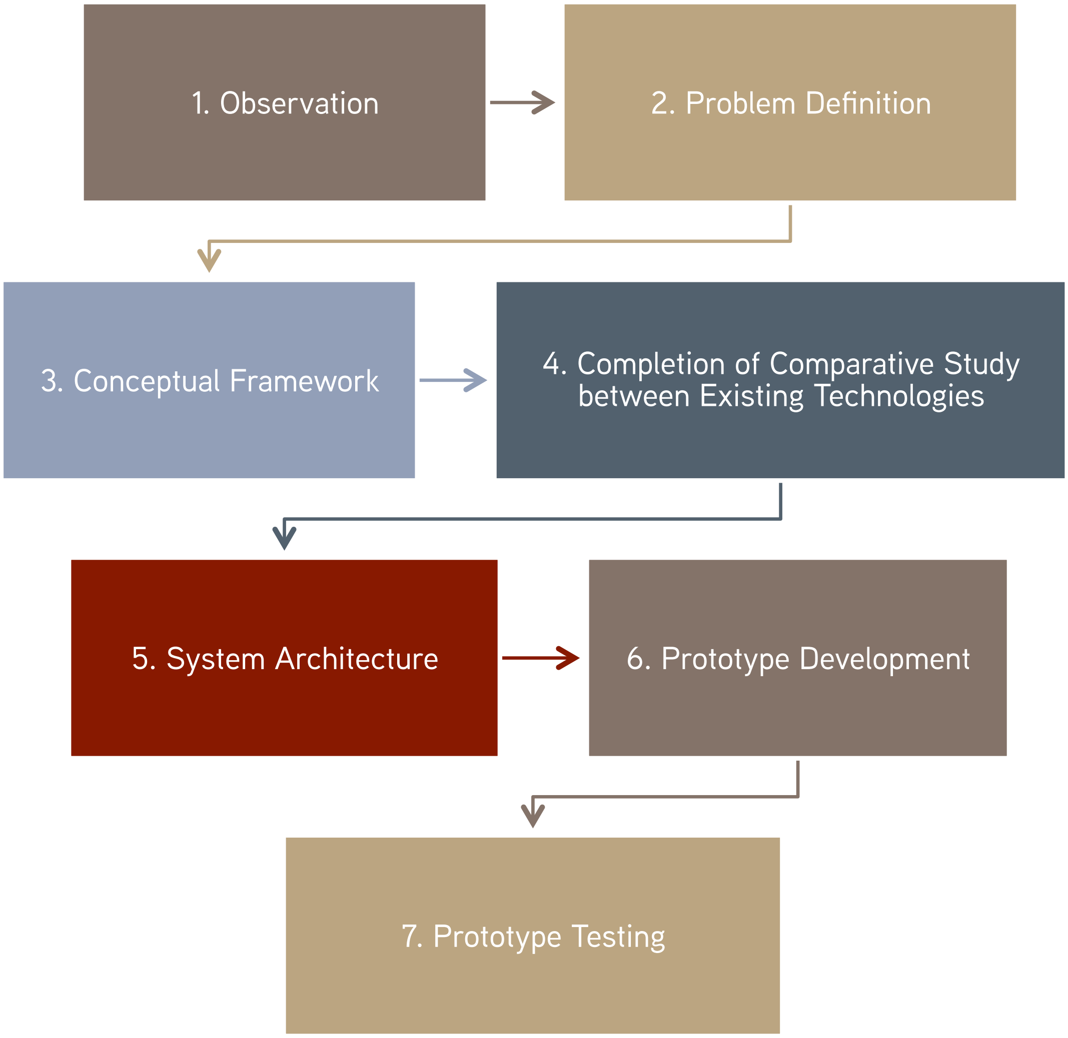



FIGURE 1. Research Method for Pre-Flood Warning System

## 3.1 Observation

In Malaysia, the occurrence of flood cannot be totally prevented, as it is a natural result from the cyclical monsoons that hit Malaysia from October to March each year. However, there is still no specific flood management plan being implemented to deal with flood disasters before, during and after the event. In Japan particularly, they already have a special law that enables a special council to manage disasters to ensure that the losses can be mitigated. Based on these observations, it is important to come out with a solution that helps the country to prepare for the flood disaster. Thus, an effective and economical means of pre-flood warning system must be implemented in Malaysia to reduce live loss and property damage.

## 3.2 Problem Definition

In this section, a problem statement is defined to narrow down the scope of the project. The main focus of this research project is to develop an early warning system that overcomes the lacks of the existing system. The existing system lacks in monitoring water level accurately, giving immediate warning notifications and offering a well-organized coordination to accelerate the evacuation process. Apart from that, when developing a warning system for flood disaster, limited communication during the occurrence of flood and the availability of electricity should also be taken into account. Therefore, in this pre-flood warning system, solar cell will be used as main power supply and warning SMS will be broadcasted before the flood occurs. This is done to keep the victims well informed of what to do and where to go in order to lessen flood losses and minimize the post-effects.

## 3.3 Conceptual Framework

Based on the observation and identification of problem, a conceptual framework for the pre-flood warning system illustrated in Figure 2 is designed.

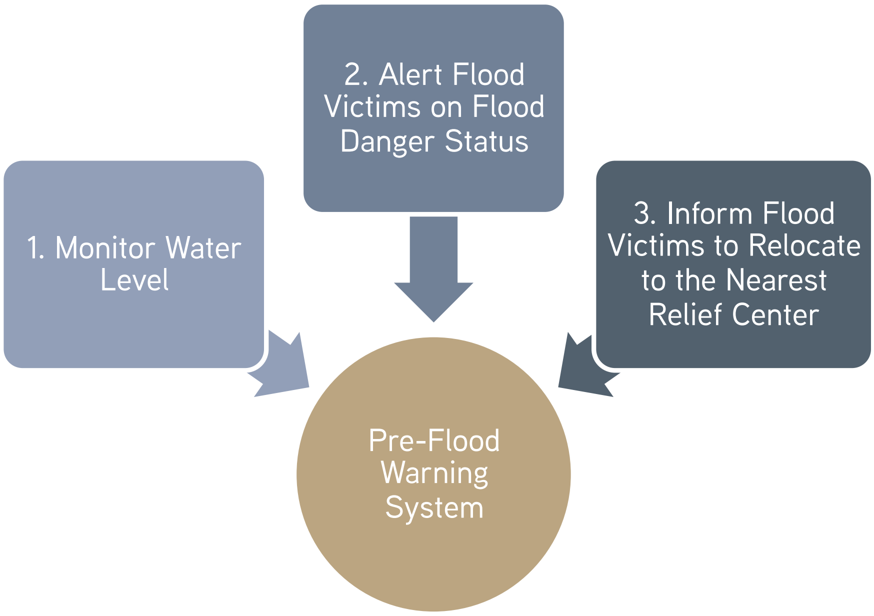



FIGURE 2. Conceptual Framework of Pre-Flood Warning System

The conceptual framework in Figure 2 signifies that there are three (3) main stages involved in pre-flood warning system. The first stage of the system focuses on monitoring water level at riverbanks to determine the danger status. Based on the danger status, stage two of the system plays a significant role of alerting residents, passersby and local authorities in the affected area regarding the flood danger status. The third stage of the system involves data broadcast as the system informs all victims to relocate to the nearest relief centre immediately.

### 3.4 Completion of Comparative Study between Existing Technologies

Before proposing a suitable architecture for this system, necessary data needs to be gathered and analyzed for better interpretation of the project. A comparative study on several areas relevant to this research project was conducted to assist the decision making process. The purpose of conducting the comparative study is to select the right tools and implement the right technology that is suitable. Decision is made based on the application of latest technology, the performance of the tools, and how the implementation of the technology and the tools could benefit the proposed pre-flood warning system to become an effective warning system.

### 3.5 System Architecture

After the completion of the comparative study between the existing technologies and with the formulated conceptual framework as basis, system architecture for this research project is designed. The system architecture is used to provide a clear representation on how the system works with a description of the equipment that is to be implemented in this project. Chapter 5 discusses in detail the proposed system architecture.

### 3.6 Prototype Development

The development of the prototype model for this research project requires the integration of hardware and software component. The prototype model is built using a medium sized plastic aquarium, a hand pump, HC-SR04 ultrasonic sensor, Arduino UNO R3 and IComsat GSM Shield. As illustrated in Figure 3, the aquarium tank is divided equally into three (3) partitions to indicate three (3) level of water namely high, medium and low.

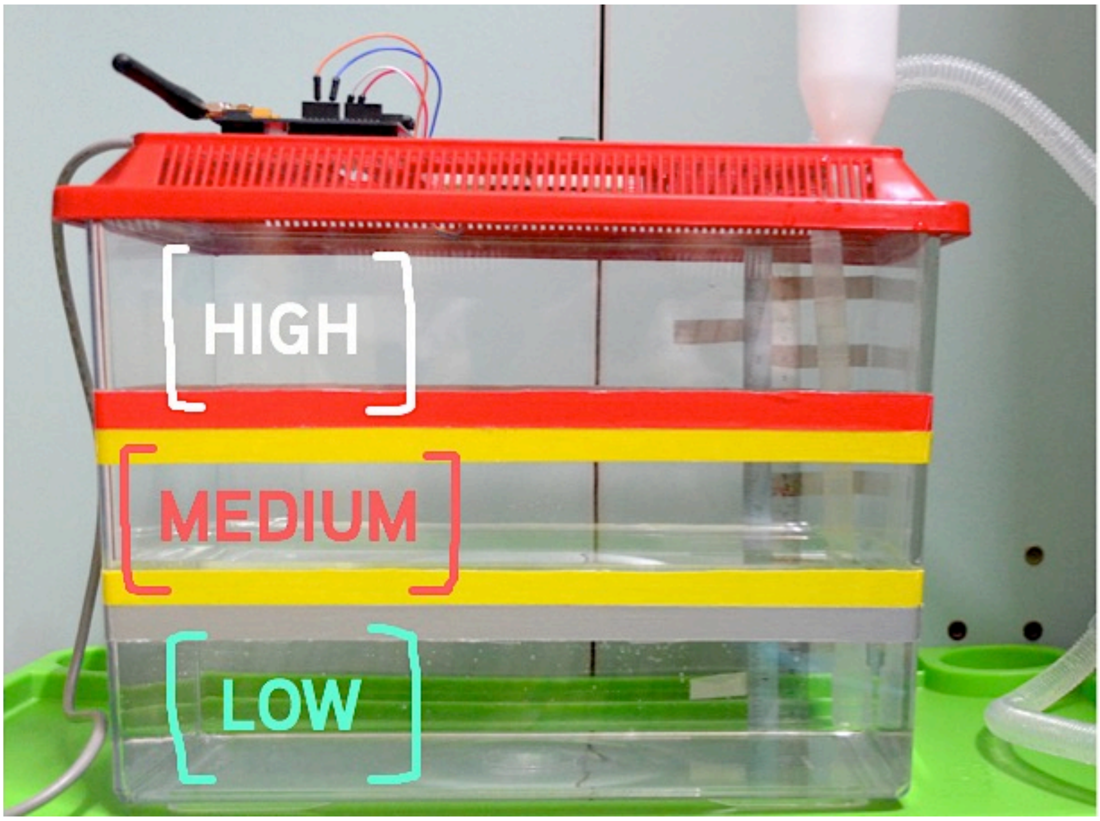



FIGURE 3. Labeling on the Aquarium Tank

Based on the partitions, a pre-determined threshold has been initialized in the program source code. However, the threshold value can be changed accordingly in the source code via Arduino IDE. Table 5 shows the threshold value used to indicate the water level that is implemented for the prototyping purposes of this research project.

TABLE 5. Threshold Value for Water Level Indicator

| Water Level | Distance between Water Surface and Ultrasonic Sensor |
|---|---|
| High | 1.1 cm to 8.0 cm |
| Medium | 8.1 cm to 15.0 cm |
| Low | 15.1 cm to 23.0 cm |

### 3.7 Prototype Testing

After the completion of prototype development, prototype testing will be conducted to validate the proposed prototype system. Besides, three (3) types of test will be carried out to evaluate the system's reliability when it operates in real environment. The tests include accuracy testing, system testing and performance testing. Based on the results gathered, continuous enhancement will be made to increase the effectiveness and efficiency of the proposed system.

# CHAPTER 4
# SYSTEM MODEL

Figure 4 shows the overview of the system model for pre-flood warning system. System model is created to demonstrate the relationship between the hardware and software components embedded in the system. The interaction between each component is briefly explained in this chapter.

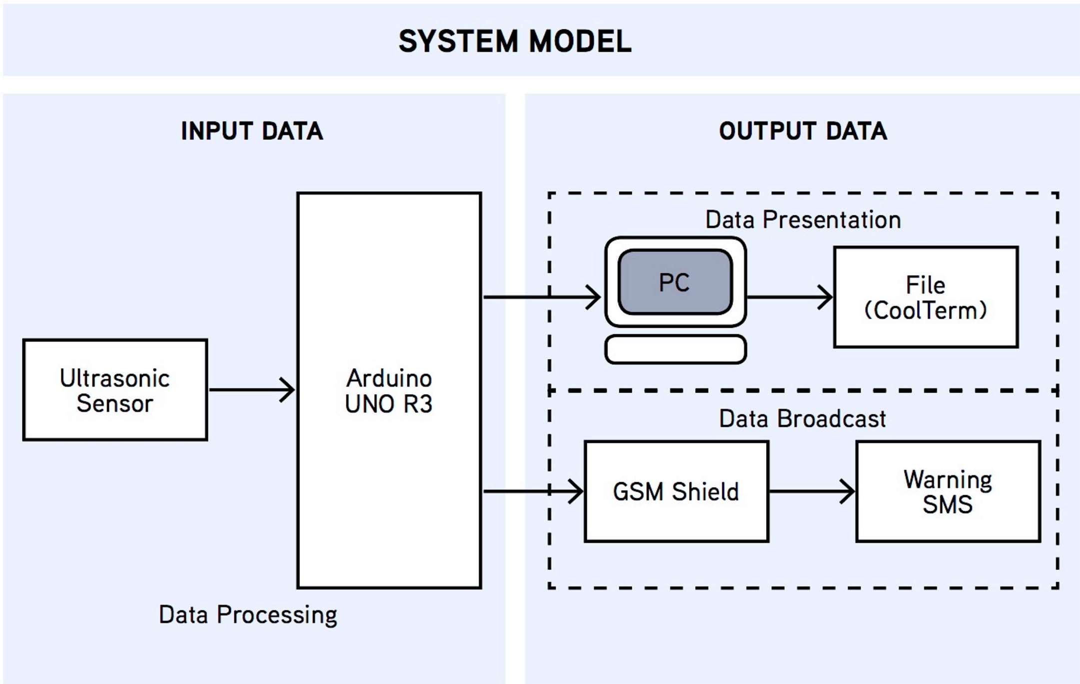



FIGURE 4. System Model for Pre-Flood Warning System

## 4.1 Hardware Components

### 4.1.1 HC-SR04 Ultrasonic Sensor

In this project, a HC-SR04 ultrasonic sensor is primarily responsible for data processing. It is capable of providing an excellent non-contact range detection with high accuracy and stable readings. Similar to radar and sonar, an ultrasonic sensor works on a principle of interpreting echoes from sound waves [15].

Figure 5a and Figure 5b shows the connection between ultrasonic sensor and microcontroller, which is linked via a 5.5 cm x 8.5 cm breadboard.

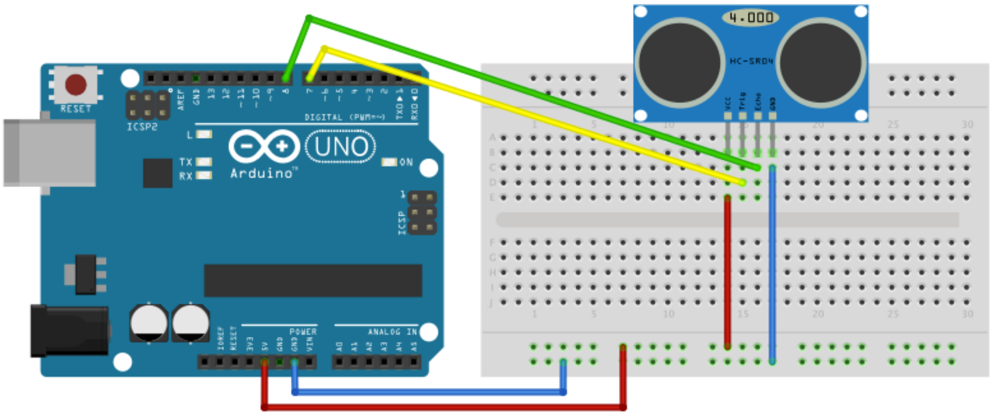



FIGURE 5a. Illustration of the Connection between Ultrasonic Sensor and Arduino UNO R3

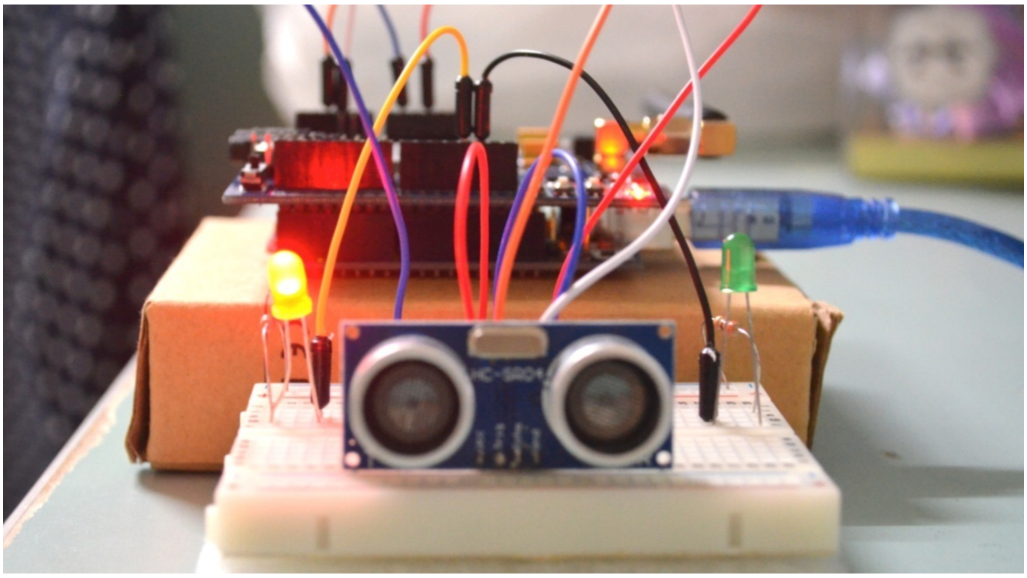


FIGURE 5b. Real Implementation of the Connection between Ultrasonic Sensor and Arduino UNO R3

For prototype system development, the ultrasonic sensor is placed upside-down facing the surface of water, similar to the illustration showed in Figure 6.

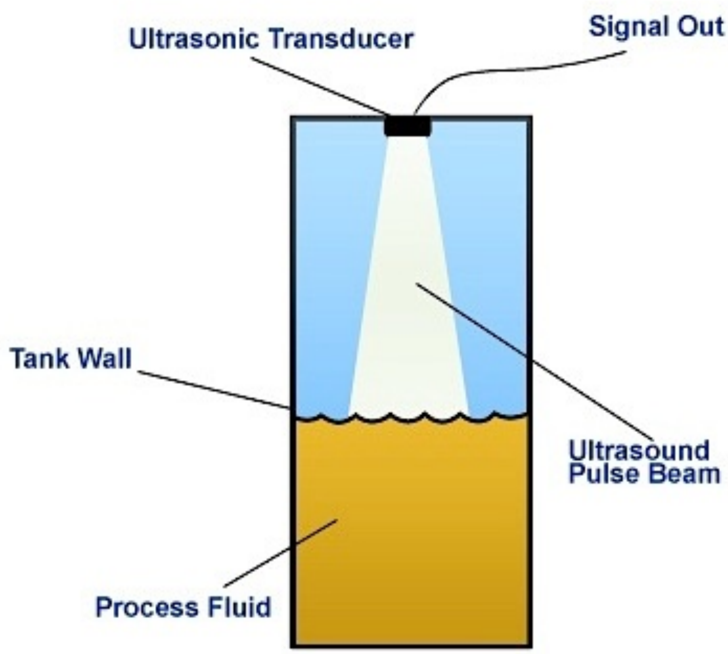



FIGURE 6. The Operation of Ultrasonic Transducer [2]

Based on Figure 6, the ultrasonic sensor measures the distance between transducer and water surface. The ultrasonic sensor consists of a transmitter and receiver. The transmitter transmits electromagnetic signal in pulses towards the water surface. The signal is reflected once it touches the water surface and collected by the receiver. The sensor then records the travelling time taken for the signal to propagate from the transmitter towards the water surface, and reflected back towards the receiver. Ultrasonic sensor used frequencies in the tens of kilohertz range with transit times of ~6 ms/m and the speed of sound is 340 m/s in air [2].

### 4.1.2 Arduino UNO R3

Figure 7 shows the starter kit of Arduino UNO R3 used in this project. Arduino is a microcontroller based on ATmega328 that integrates GSM shield and ultrasonic sensor. Arduino will process the data gathered from the ultrasonic sensor before the data is passed to the GSM shield to broadcast the SMS.

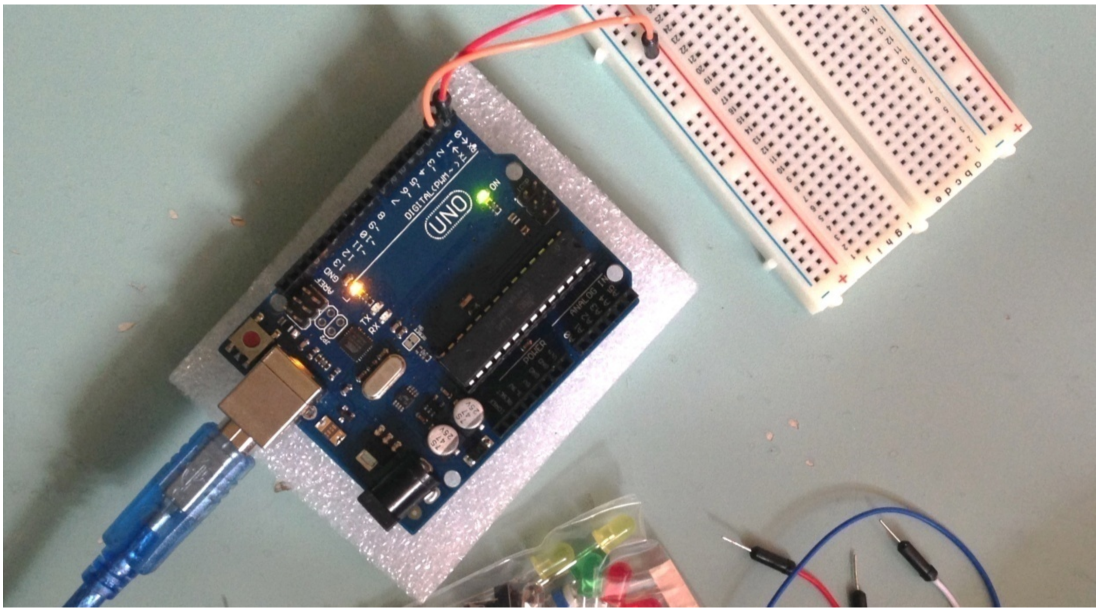



FIGURE 7. Arduino UNO R3 Starter Kit Student Edition

### 4.1.3 IComsat SIM900 GSM/GPRS Shield

GSM shield is responsible for data broadcasting of pre-flood warning system. It is inserted with a SIM card from a service provider. This GSM shield is designed for Arduino based on SIM900 quad-band and it is used to broadcast warning SMS to residents, local authorities and passersby.

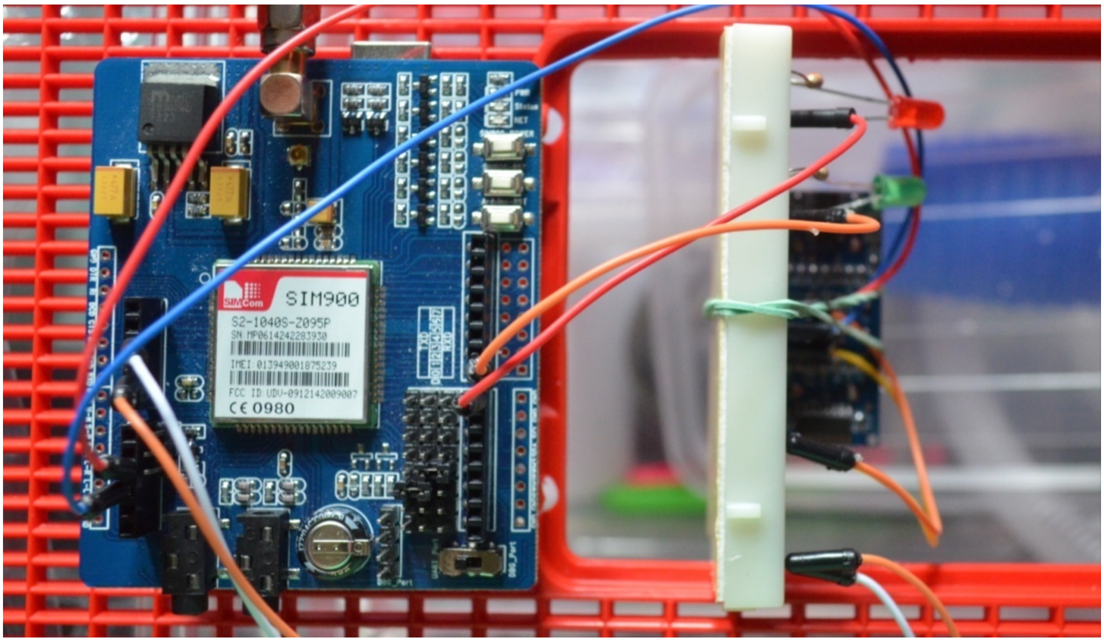



FIGURE 8. IComsat SIM900 GSM Shield

Figure 8 shows that the GSM shield is integrated with Arduino by attaching it on top of the microcontroller. The GSM shield and Arduino is then integrated with the ultrasonic sensor via wires through the Arduino interface. The receive ($R_XD$) and transmit ($T_XD$) digital pins of Arduino is set at 0 and 1 to establish connection from Arduino to the GSM shield. For the connection from the GSM shield to Arduino, $R_XD$ and $T_XD$ of GSM shield is set at digital pin 2 and 3. This positioning is done at the Arduino interface on the GSM shield.

Based on the assumption made from the mobility of subscribers, by leveraging on the MTSO technology, the GSM shield will be connected to the nearest cell tower where the sensor is parked. This is done to ensure that warning SMS is broadcasted and delivered only to the residents, local authorities and passersby that reside in the affected flooding area.

### 4.1.4 Mobile Phone

Figure 9 shows the mobile phone that was used to receive warning SMS from the pre-flood warning system.

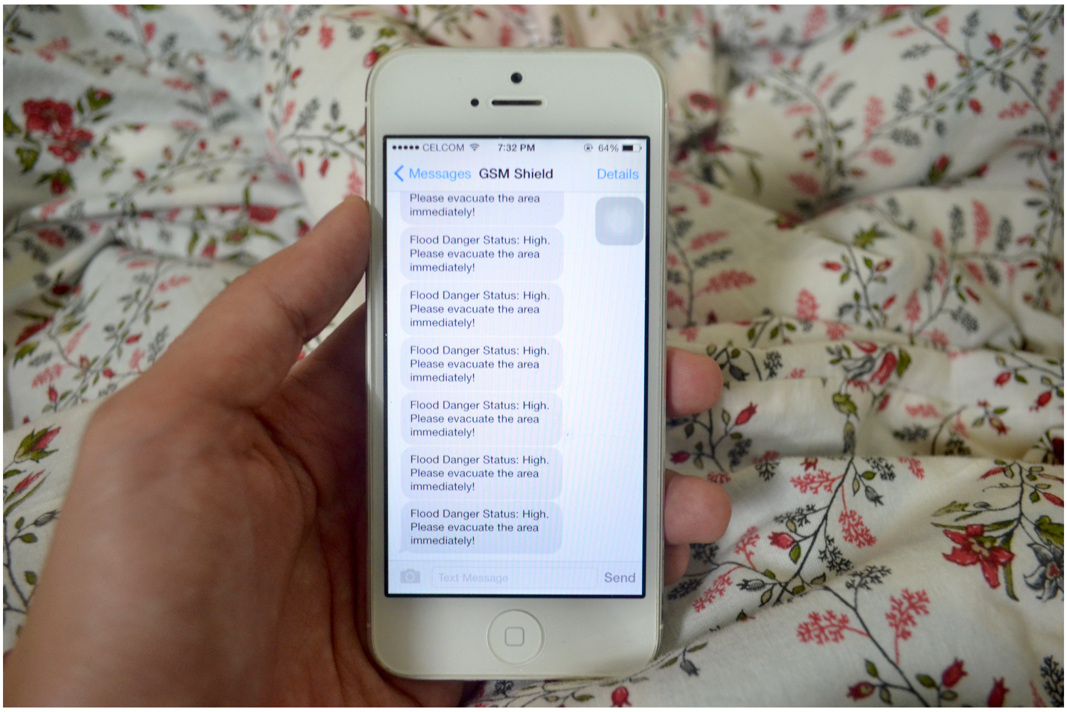



FIGURE 9. Mobile Phone that Acts as Receiver

## 4.2 Software Components

### 4.2.1 Arduino Software (IDE) Version 1.6.5

The microcontroller functions as programmed. The programs are written, compiled and executed via the Arduino IDE. The IDE was installed on a terminal (laptop) connected to the microcontroller via a USB cable. When executing the program, the IDE will produce a monitoring window, termed as Serial Monitor, which shows the output of the program as illustrated in Figure 10.

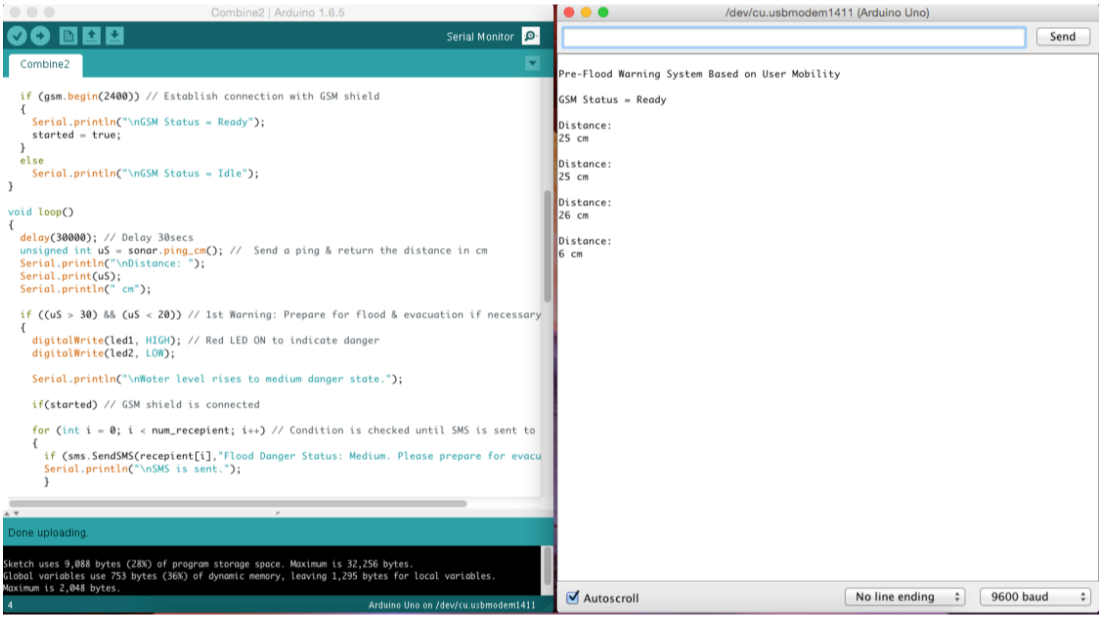


FIGURE 10. Screenshot of Arduino IDE after Running a Program with its Output Displayed on Serial Monitor

Arduino IDE offers advantages in terms of [16]:

- Cross-platform: Arduino IDE runs on Windows, Macintosh OSX and Linux operating systems
- Simple and clear programming environment: Arduino programming environment is easy to use for beginners
- Open source development environment and extensible software

### 4.2.2 CoolTerm Version 1.4.5

For data presentation, CoolTerm version 1.4.5 was used for the purpose of exporting data to Microsoft Excel and generating graph of the data collected from the ultrasonic sensor. A screenshot of CoolTerm monitoring window, which displays the output of the program is displayed in Figure 11.

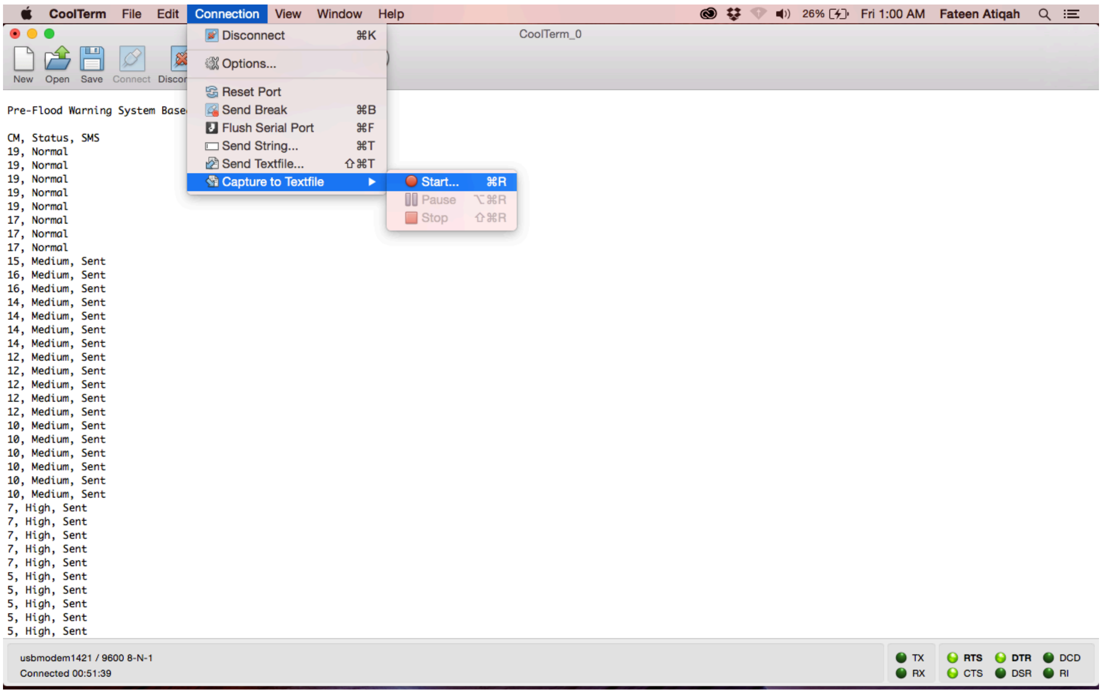



FIGURE 11. Screenshot of CoolTerm while Running a Program

CoolTerm is a simple serial port terminal application that functions by establishing connection to the serial port used by Arduino IDE to communicate with the board [17]. CoolTerm runs on MAC OSX, Windows and Linux operating systems.

# CHAPTER 5
# RESULTS AND DISCUSSION

An experiment with controlled water rising effect was conducted to validate the prototype system for the proposed system architecture. Thus, Chapter 5 discusses on the results, which consists of system architecture, source code, prototype testing and problems encountered and solutions implemented to overcome the problems.

## 5.1 System Architecture

As illustrated in Figure 12, the pre-flood warning system consists of three main systems; data processing, data presentation and data broadcast.

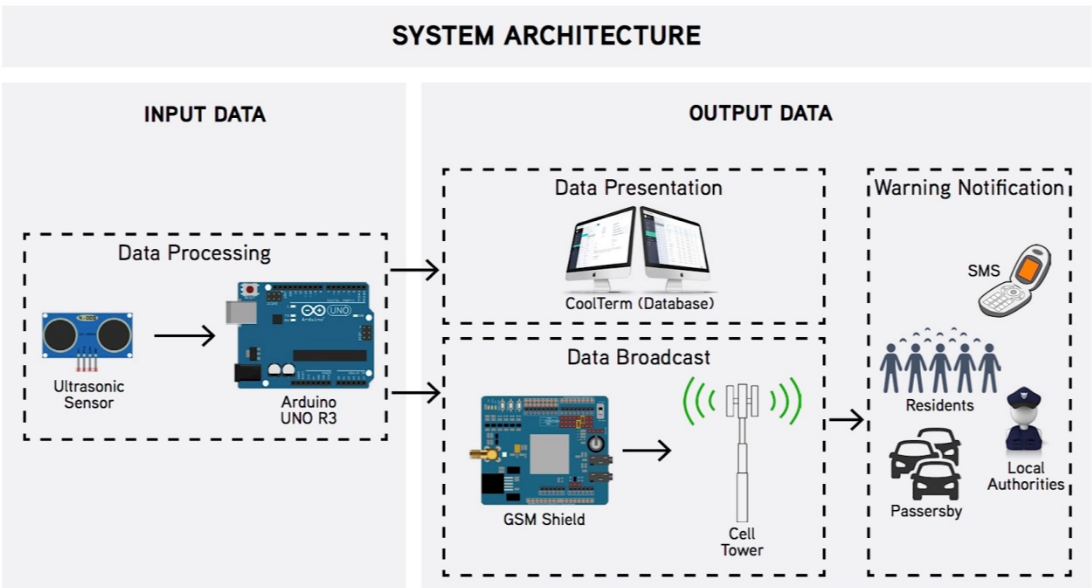



FIGURE 12. System Architecture of Pre-Flood Warning System

Data processing involves the collection of data from ultrasonic sensor, which will be installed at riverbanks to measure water levels. Data gathered from the ultrasonic sensor will be sent to Arduino, a microcontroller that compares the water levels (i.e. low, medium and high) with a pre-determined threshold. Once water level exceeds the pre-determined threshold, the microcontroller will instruct GSM shield to send warning messages. Warning SMS will be broadcasted to all users and local authorities within the affected area for evacuation process. By leveraging on MTSO technology, the GSM shield will be connected to the nearest cell tower in order to get a list of users registered in the particular area of flooding. Thus, warning SMS is broadcasted based on the assumption from the mobility of users in order to increase the effectiveness and efficiency of pre-flood warning system. Data flow diagram in Figure 13 shows the algorithm flow of the code that has been programmed into the Arduino microcontroller via the IDE.

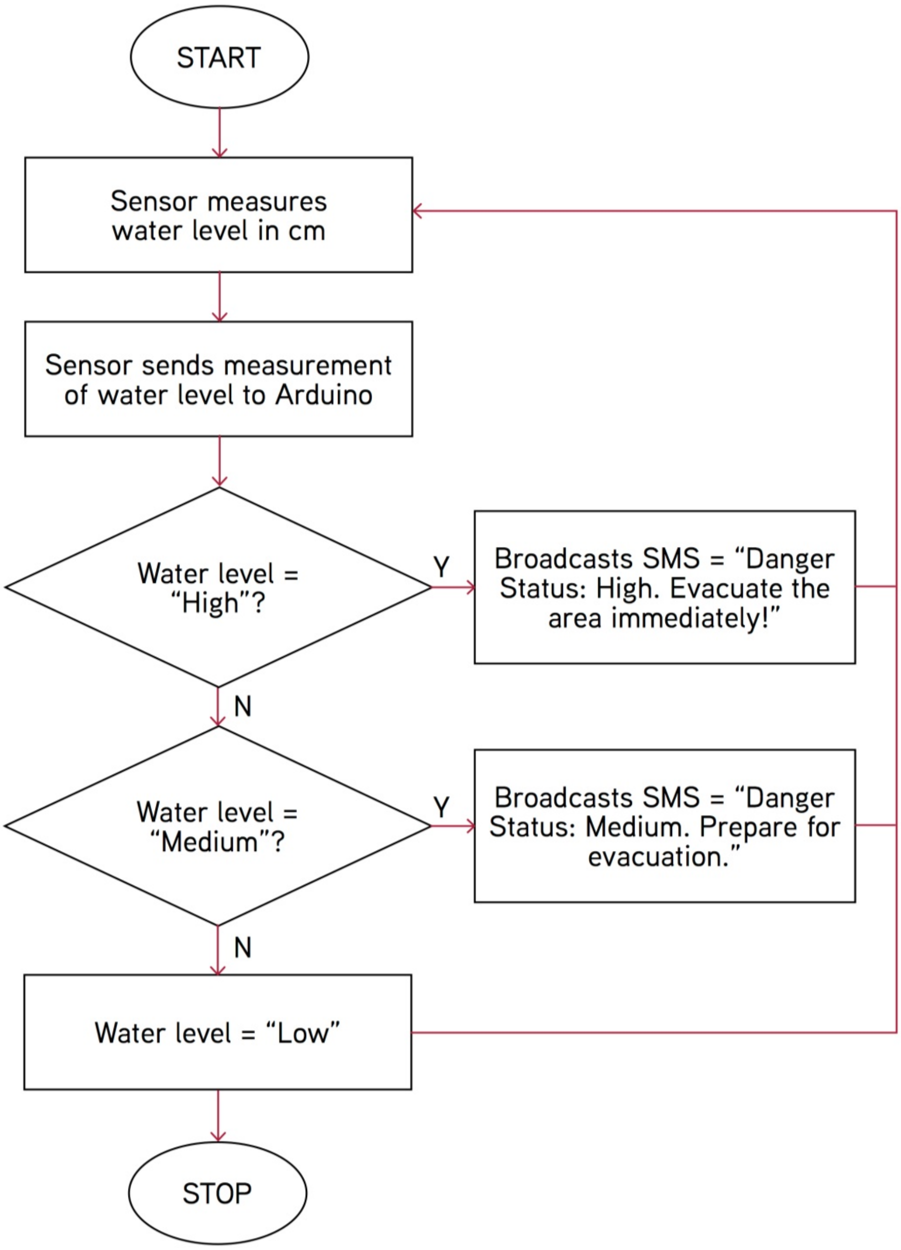



FIGURE 13. Data Flow Diagram of Pre-Flood Warning System

## 5.2 Source Code

### 5.2.1 Establishing Connection with GSM Shield

It is addressed in Chapter 4 that GSM shield is responsible to broadcast warning SMS to residents, local authorities and passersby. The GSM shield will receive command from Arduino before it broadcasts warning SMS to the receiver side. Thus, it is important to have a stable connection between serial port and the GSM shield. The right way to establish the connection is shown in Code Snippet 1.

```
00 #include "SIM900.h"
01 #include <SoftwareSerial.h>
02
03 boolean started = false;
04
05 voidsetup(){
06   Serial.begin(9600);
07   Serial.println("\nPre-Flood Warning System Based on User
08   Mobility");
09
10   if (gsm.begin(9600)){// Establish connection
11         Serial.println("\nGSM Status = Ready");
12         started = true;
13   }
14   else
15         Serial.println("\nGSM Status = Idle");
16 }
```

Code Snippet 1.

From Code Snippet 1, Line 00 shows that the system loads `"SIM900.h"` library that contains the configuration of receive and transmit digital pins ($R_XD$, $T_XD$) for the GSM shield. Line 01 shows the `<SoftwareSerial.h>` header is included as it holds the serial pins functions for the GSM shield.

Line 06 denotes port initialization, which needs to be done for all hardware component detected by the communication port. Baud rate specifies how fast data is sent over a serial line from device A to device B. In this research project, the baud rate from Arduino to the GSM shield is initialized at 9600 bps. After the communication port is opened, it will find the baud rate that matches with the baud rate of GSM shield, which is set at 9600 bps as shown in Line 10. The baud rate can be just about any value as the only requirement is that both devices operate at the same rate [18].

### 5.2.2 Send and Receive SMS

Immediately after the connection for the GSM shield is established and communication port is opened, a program that enables Arduino to send and receive SMS, to and from multiple clients is uploaded to the board. Code Snippet 2 shows how it is done using array. For prototyping purposes, the SMS character limit is initialized at 200 characters per warning SMS as displayed in Line 05. The number of recipient is set to two (2) as shown in Line 07. However, this value can be changed according to the experiment setting.

```
00 #include "sms.h"
01 SMSGSM sms;
02
03 char position;
04 char phone_number[20];
05 char sms_limit[200];
06
07 int recipient = 2; // Depends on number of recipient
08 char recepient[2][20] = "+60198765432","+60123456789";
```

Code Snippet 2.

Line 00 of Code Snippet 3 implies that when the GSM shield is connected, the condition `(int i = 0; i < recepient; i++)` in Line 01 is checked using the if-else statement from Line 03 to Line 08 of Code Snippet 3. The condition is checked until warning SMS is sent to all recipients.

```
00 if (started)
01  for (int i = 0; i < recepient; i++){
02
03  if (sms.SendSMS(recepient[i], "Flood Danger Status:
04  Medium. Please prepare for evacuation.")){
05        Serial.println("\nSMS is sent.");
06  }
07  else
08        Serial.println("\nError sending SMS.");
09  }
```

Code Snippet 3.

For retrieving SMS that comes in, Code Snippet 4 is added inside `voidloop()` to ensure the system checks for new and unread SMS in every 60 seconds interval as shown in Line 01. Executing the code in Line 06 will display the new and unread SMS on serial monitor. The serial monitor will display the position of unread SMS in the inbox together with the phone number of the sender and the messages that comes with it as shown in Line 05 to Line 08.

```
00 if(started){
01  position = sms.IsSMSPresent(SMS_UNREAD);
02
03  if(position){
04        Serial.print("\nSMS position: ");
05        Serial.println(position,DEC);
06        sms.GetSMS(position, phone_number, sms_limit, 200);
07        Serial.println(phone_number);
08        Serial.println(sms_text);
09  }
10 delay(60000);
11 }
```

Code Snippet 4.

### 5.2.3 Reading Value from Communication Port

Ultrasonic sensor is connected to Arduino and linked to the communication port via USB 3.0 cable. Code Snippet 5 shows how the initialization for the ultrasonic sensor is done. The `"NewPing.h"` library in Line 00 is loaded to enable the ultrasonic sensor to send multiple sonar pulses.

```
00 #include "NewPing.h"
01
02 #define echo_pin A2 // Input
03 #define trig_pin A3 // Output
04 #define max_distance 200 // Set distance limit
05
06 NewPing sonar.ping_cm(trig_pin, echo_pin, max_distance);
```

Code Snippet 5.

The ultrasonic sensor will send multiple sonar pulse and return the distance in centimetres or zero (0) if no sonar echoed within the distance defined in Line 04. The `NewPing sonar.ping_cm` in Line 06 indicates the initialization of trigger pin as output, echo pin as input and maximum distance for the ultrasonic sensor to ping.

```
00   unsignedint uS = sonar.ping_cm();
01   Serial.println("\nDistance: ");
02   Serial.print(uS);
03   Serial.println(" cm");
```

Code Snippet 6.

Code Snippet 6 shows how the system converts the water level in terms of distance from the sensor to the water surface. Line 00 to Line 02 shows how the system retrieves the value and prints it on serial monitor.

### 5.2.4 Data Extraction using CoolTerm

After the source code is uploaded in Arduino, the network status of the communication port and the GSM shield is verified. If the port is opened and the GSM shield is connected, open CoolTerm application in a new window. A step-by-step photo screenshot to assist port configuration process for CoolTerm is shown in Figure 14 to Figure 20.

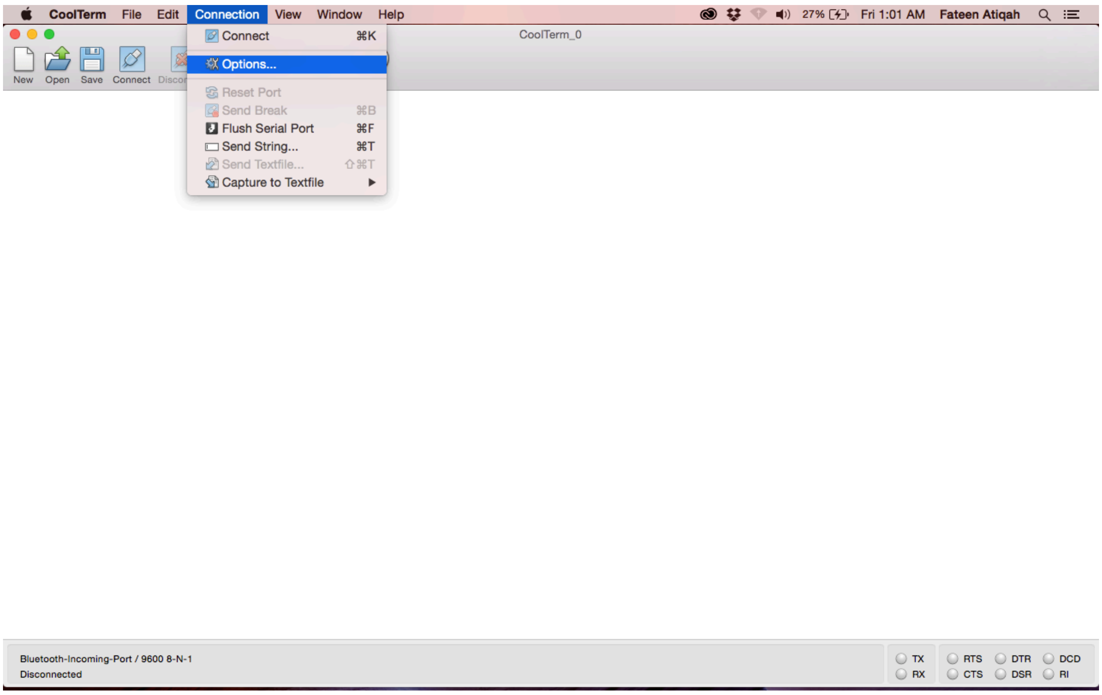



FIGURE 14. Network Connection Configurations (Step 1 of 7)

As shown in Figure 14, go to *Options* to configure the network settings of CoolTerm in order to establish connection to the same communication port as Arduino.

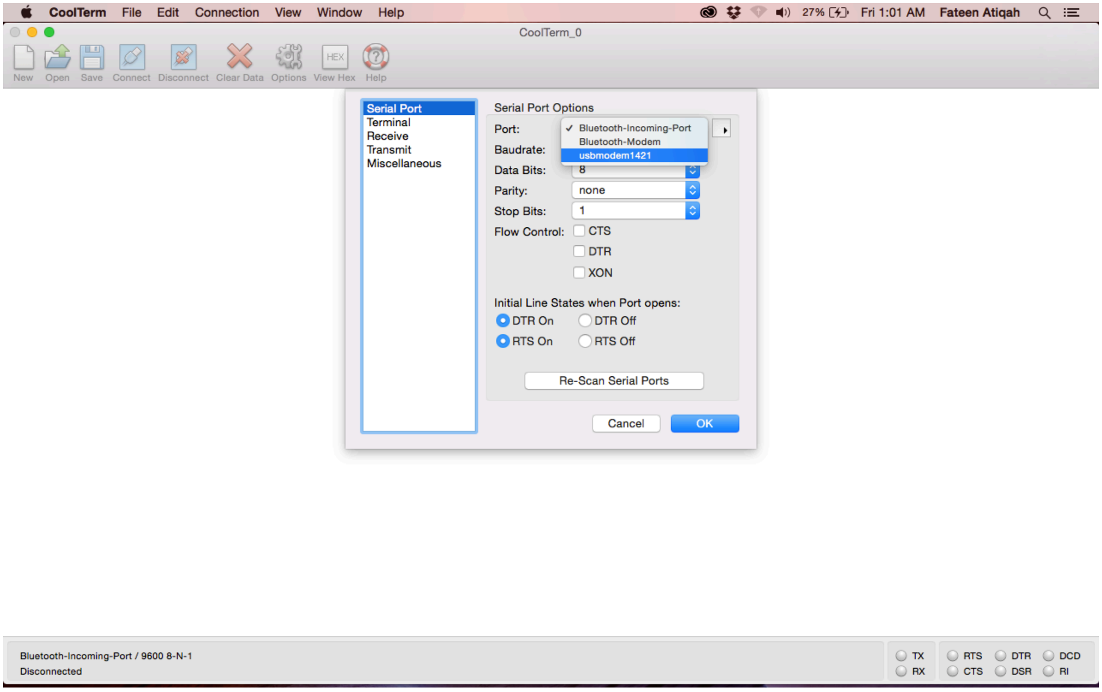



FIGURE 15. Serial Port Configurations (Step 2 of 7)

Referring to Figure 15, *Port* must be the same with the serial port configured to communicate with the Arduino from the IDE. *Baudrate* is set according to the pre-initialized baud rate in the Arduino source code with 8 *Data Bits*. In *Terminal Options* shown in Figure 16, select *Raw Mode* to get the data just as it is.

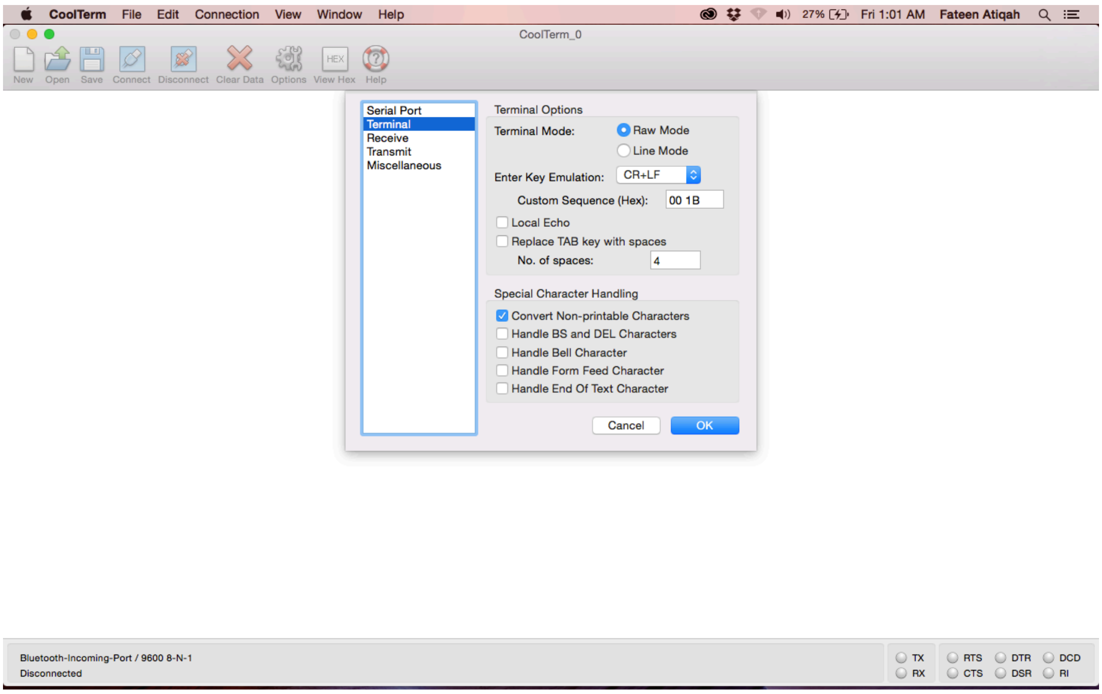



FIGURE 16. Terminal Configurations (Step 3 of 7)

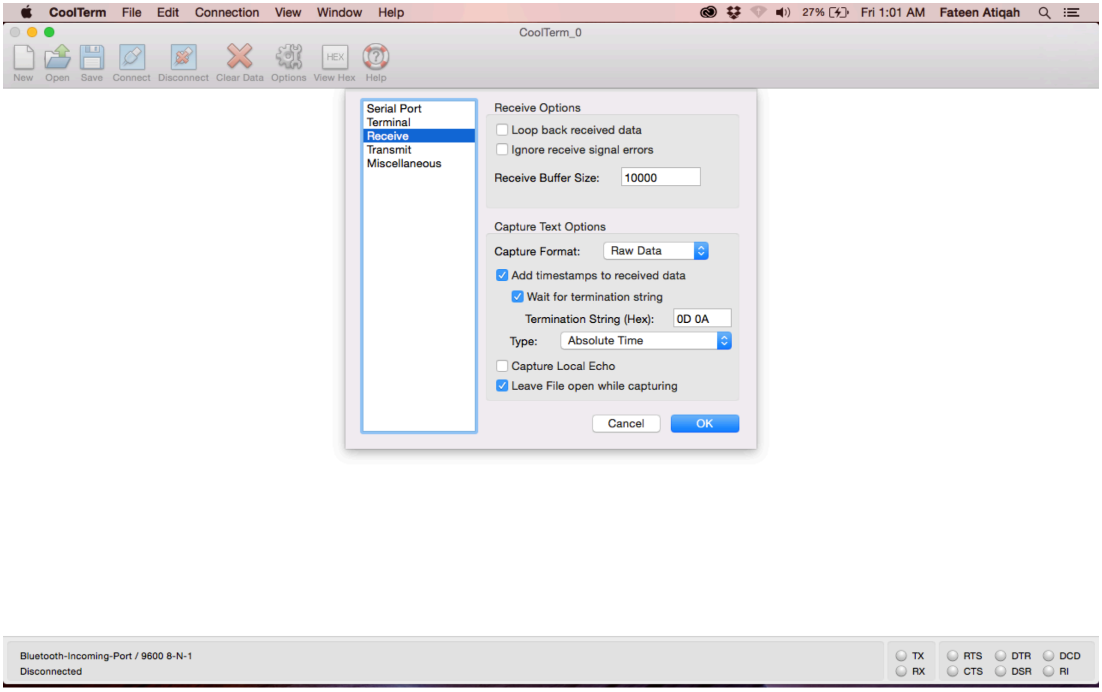



FIGURE 17. Receive Options Settings (Step 4 of 7)

Figure 17 shows timestamps format of *Absolute Time* is selected to add timestamps to the received data from the ultrasonic sensor. The file is being left open while the data capturing process is happening. In Figure 18, *Notify after sending text file* in *Send Text Options* is selected to get notifications after the process is completed.

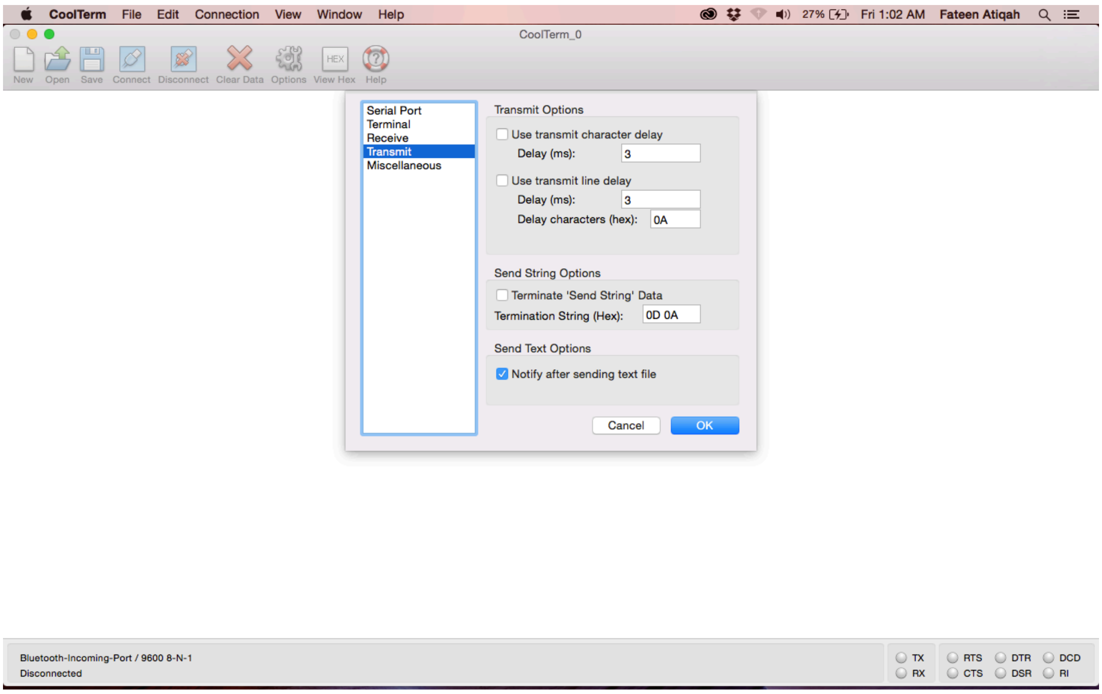



FIGURE 18. Transmit Configurations (Step 5 of 7)

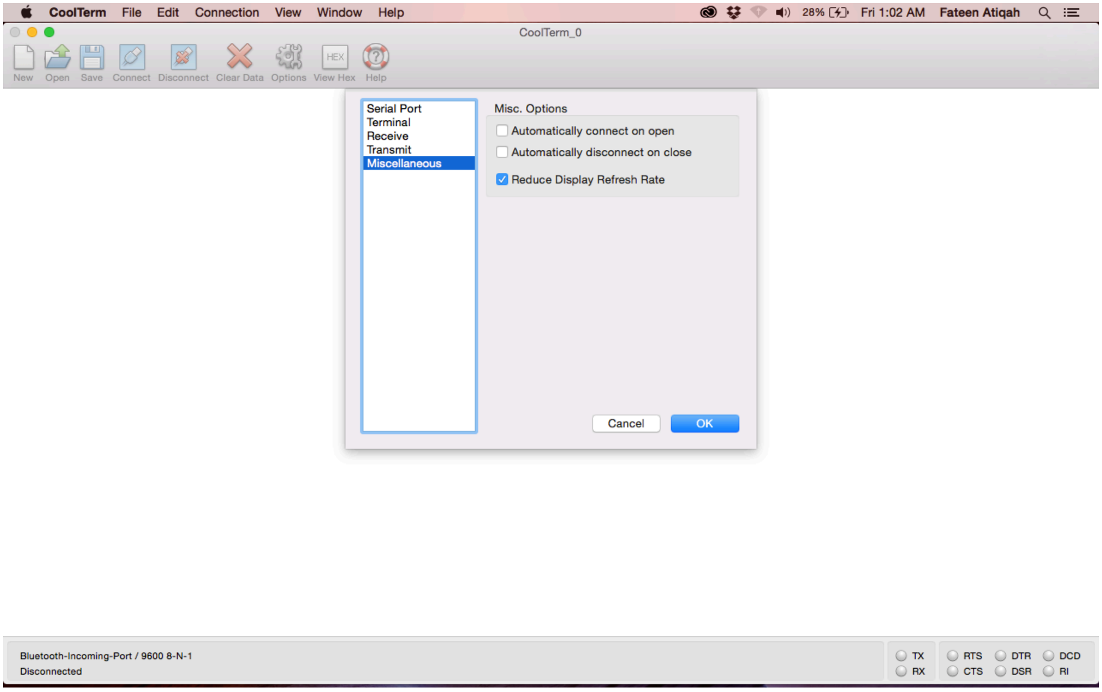



FIGURE 19. Miscellaneous Configurations (Step 6 of 7)

*Reduce Display Refresh Rate* tab is selected in Figure 19 to minimize the needs of CoolTerm to reload as it retrieves new data. Once the configuration is done, click *Connect* to start communicating with the Arduino. Then, go to *Connection* as shown in Figure 20, hover to *Capture to Textfile* and select *Start* to begin recording data.

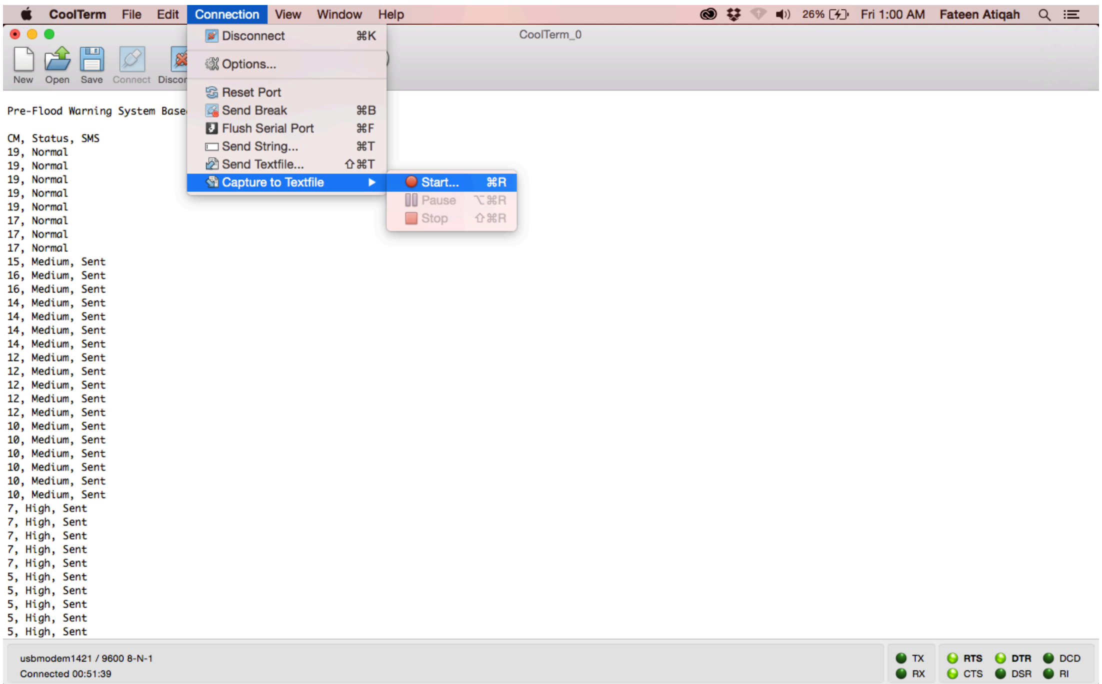



FIGURE 20. Final Step of Capturing Data (Step 7 of 7)

### 5.2.5 XLS (Excel) Exports

CoolTerm application and Microsoft Excel plays an important role in data presentation system as it enables data to be monitored accurately. This allows statistics to be generated from time to time in order to improve the effectiveness and efficiency of this pre-flood warning system. Once data recording stopped and desired data is captured, CoolTerm will export it to a text file with .txt extension. For further data processing, it is advisable to open the text file in Microsoft Excel and start generating graphs and tables from there.

Figure 21 to Figure 24 demonstrates the four (4) steps applied to extract the data from .txt to .xls.

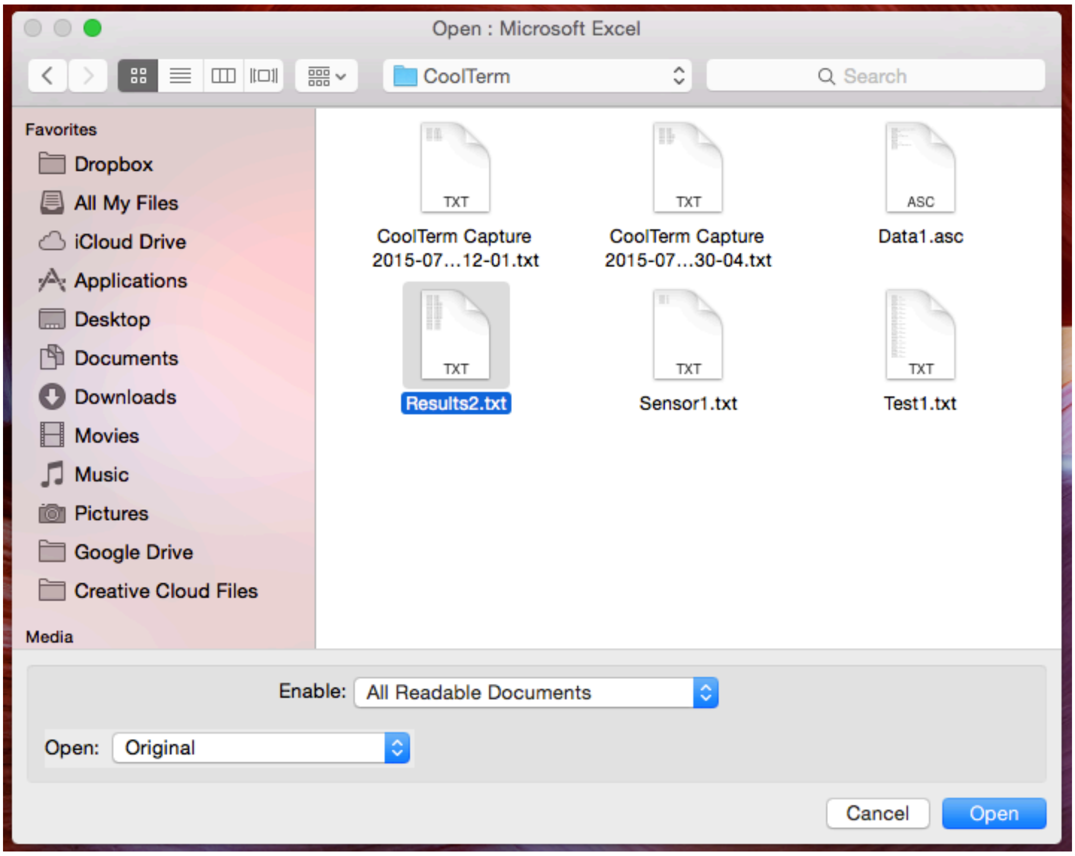



FIGURE 21. Open .txt File in Microsoft Excel (Step 1 of 4)

Step 1 of 4 illustrated in Figure 21 shows Microsoft Excel application is opened in a new window and *Results2.txt* file is selected to open.

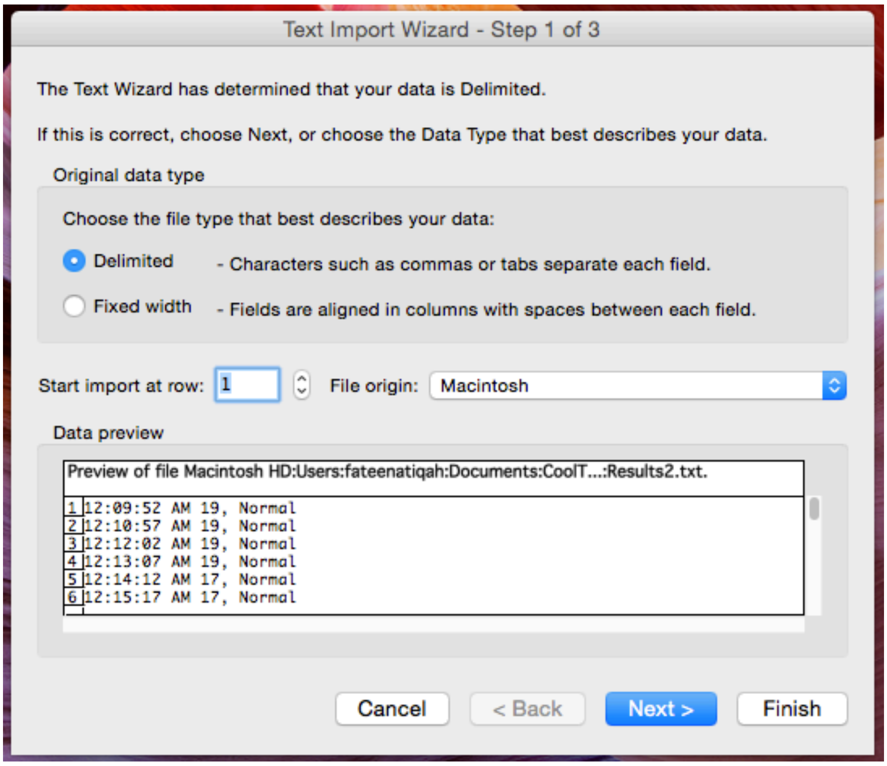



FIGURE 22. Text Import Wizard Settings (Step 2 of 4)

As shown in Figure 22, *Delimited* is chosen and the *Next* button is clicked. *Delimiters* of *Tab* and *Comma* were selected next in Step 3 as shown in Figure 23.

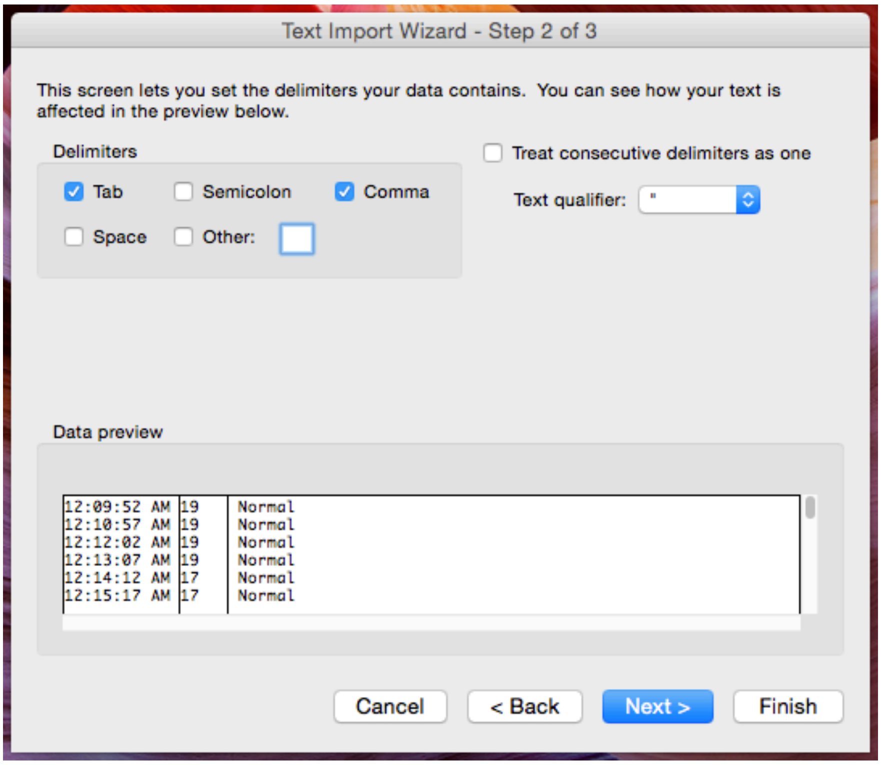



FIGURE 23. Text Import Wizard Settings (Step 3 of 4)

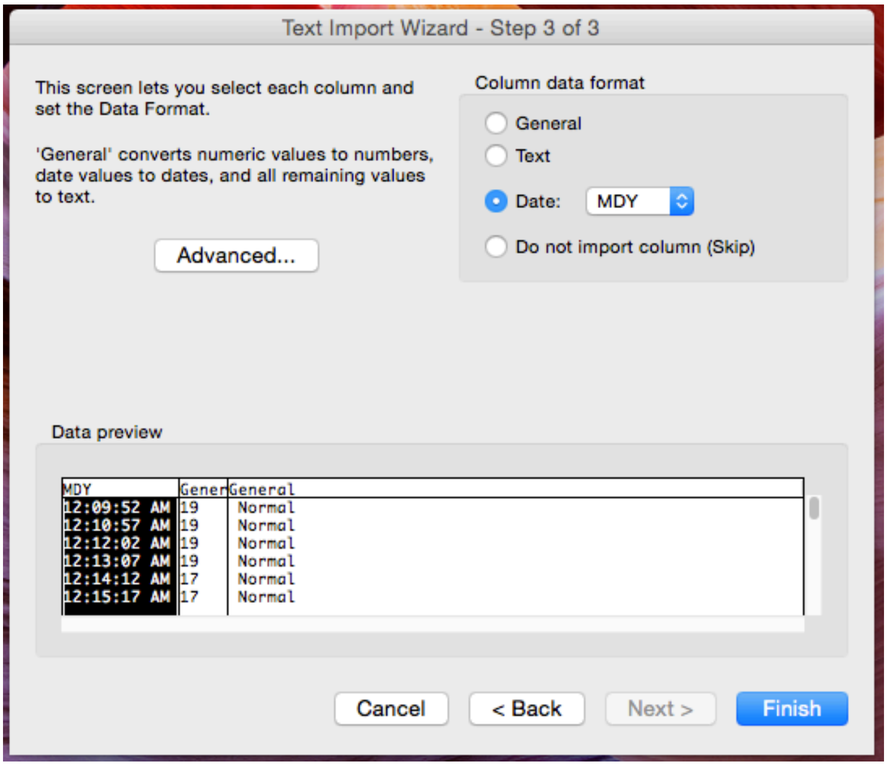
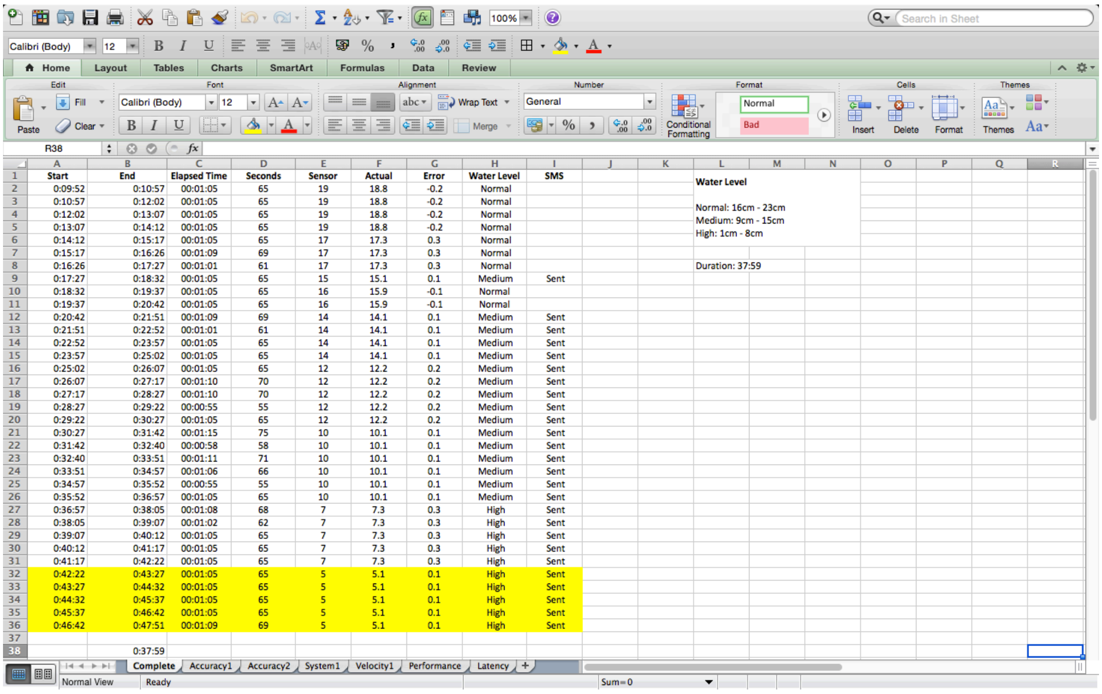



FIGURE 24. Text Import Wizard Settings (Step 4 of 4)

Under *Column data format* in Figure 24, *Date* with *MDY* format is chosen and *Finish* button is clicked to save the *Text Import Wizard* settings. The overview of the data extracted is shown in Figure 25.



| Start | End | Elapsed Time | Seconds | Sensor | Actual | Error | Water Level | SMS |
|---|---|---|---|---|---|---|---|---|
| 0:09:52 | 0:10:57 | 00:01:05 | 65 | 19 | 18.8 | -0.2 | Normal | |
| 0:10:57 | 0:12:02 | 00:01:05 | 65 | 19 | 18.8 | -0.2 | Normal | |
| 0:12:02 | 0:13:07 | 00:01:05 | 65 | 19 | 18.8 | -0.2 | Normal | |
| 0:13:07 | 0:14:12 | 00:01:05 | 65 | 19 | 18.8 | -0.2 | Normal | |
| 0:14:12 | 0:15:17 | 00:01:05 | 65 | 17 | 17.3 | 0.3 | Normal | |
| 0:15:17 | 0:16:26 | 00:01:09 | 69 | 17 | 17.3 | 0.3 | Normal | |
| 0:16:26 | 0:17:27 | 00:01:01 | 61 | 17 | 17.3 | 0.3 | Normal | |
| 0:17:27 | 0:18:32 | 00:01:05 | 65 | 15 | 15.1 | 0.1 | Medium | Sent |
| 0:18:32 | 0:19:37 | 00:01:05 | 65 | 16 | 15.9 | -0.1 | Normal | |
| 0:19:37 | 0:20:42 | 00:01:05 | 65 | 16 | 15.9 | -0.1 | Normal | |
| 0:20:42 | 0:21:51 | 00:01:09 | 69 | 14 | 14.1 | 0.1 | Medium | Sent |
| 0:21:51 | 0:22:52 | 00:01:01 | 61 | 14 | 14.1 | 0.1 | Medium | Sent |
| 0:22:52 | 0:23:57 | 00:01:05 | 65 | 14 | 14.1 | 0.1 | Medium | Sent |
| 0:23:57 | 0:25:02 | 00:01:05 | 65 | 14 | 14.1 | 0.1 | Medium | Sent |
| 0:25:02 | 0:26:07 | 00:01:05 | 65 | 12 | 12.2 | 0.2 | Medium | Sent |
| 0:26:07 | 0:27:17 | 00:01:10 | 70 | 12 | 12.2 | 0.2 | Medium | Sent |
| 0:27:17 | 0:28:27 | 00:01:10 | 70 | 12 | 12.2 | 0.2 | Medium | Sent |
| 0:28:27 | 0:29:22 | 00:00:55 | 55 | 12 | 12.2 | 0.2 | Medium | Sent |
| 0:29:22 | 0:30:27 | 00:01:05 | 65 | 12 | 12.2 | 0.2 | Medium | Sent |
| 0:30:27 | 0:31:42 | 00:01:15 | 75 | 10 | 10.1 | 0.1 | Medium | Sent |
| 0:31:42 | 0:32:40 | 00:00:58 | 58 | 10 | 10.1 | 0.1 | Medium | Sent |
| 0:32:40 | 0:33:51 | 00:01:11 | 71 | 10 | 10.1 | 0.1 | Medium | Sent |
| 0:33:51 | 0:34:57 | 00:01:06 | 66 | 10 | 10.1 | 0.1 | Medium | Sent |
| 0:34:57 | 0:35:52 | 00:00:55 | 55 | 10 | 10.1 | 0.1 | Medium | Sent |
| 0:35:52 | 0:36:57 | 00:01:05 | 65 | 10 | 10.1 | 0.1 | Medium | Sent |
| 0:36:57 | 0:38:05 | 00:01:08 | 68 | 7 | 7.3 | 0.3 | High | Sent |
| 0:38:05 | 0:39:07 | 00:01:02 | 62 | 7 | 7.3 | 0.3 | High | Sent |
| 0:39:07 | 0:40:12 | 00:01:05 | 65 | 7 | 7.3 | 0.3 | High | Sent |
| 0:40:12 | 0:41:17 | 00:01:05 | 65 | 7 | 7.3 | 0.3 | High | Sent |
| 0:41:17 | 0:42:22 | 00:01:05 | 65 | 7 | 7.3 | 0.3 | High | Sent |
| 0:42:22 | 0:43:27 | 00:01:05 | 65 | 5 | 5.1 | 0.1 | High | Sent |
| 0:43:27 | 0:44:32 | 00:01:05 | 65 | 5 | 5.1 | 0.1 | High | Sent |
| 0:44:32 | 0:45:37 | 00:01:05 | 65 | 5 | 5.1 | 0.1 | High | Sent |
| 0:45:37 | 0:46:42 | 00:01:05 | 65 | 5 | 5.1 | 0.1 | High | Sent |
| 0:46:42 | 0:47:51 | 00:01:09 | 69 | 5 | 5.1 | 0.1 | High | Sent |
| | | | | | | | | |
| | 0:37:59 | | | | | | | |



FIGURE 25. Data Extraction from CoolTerm to Microsoft Excel

### 5.3 Experiment Setup

The prototype model of pre-flood warning system is developed and as proof of concept, it is tested through experimentation in a lab scale setup with controlled water rising effect. The prototype model is made up of a medium sized plastic aquarium, a hand pump, HC-SR04 ultrasonic sensor, Arduino UNO R3 microcontroller and IComsat GSM shield.

For validation purposes, three (3) tests were conducted namely accuracy testing, performance testing and system testing. The illustration of how the experiment is conducted is shown in Figure 26.

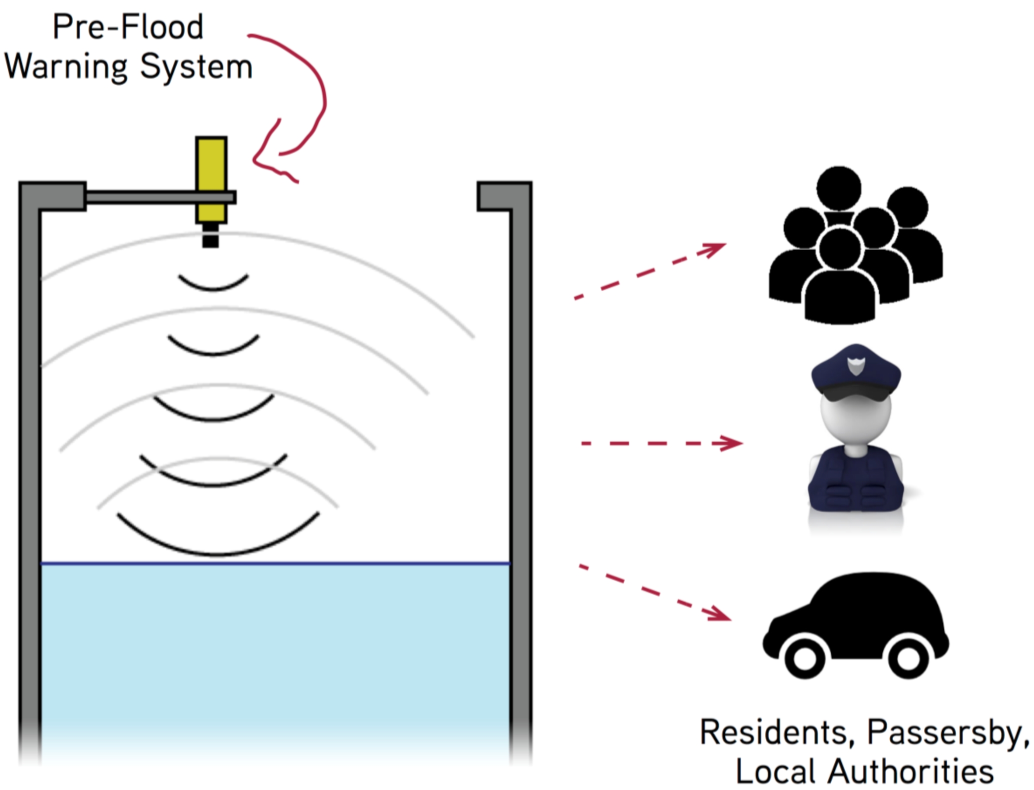



FIGURE 26. Illustration of Experiment Conducted

#### 5.3.1 Component Setup

The hardware component for this experiment includes the whole pre-flood warning system: ultrasonic sensor HC-SR04, a 5.5 cm x 8.5 cm breadboard, IComsat GSM shield and GSM antenna, Arduino UNO R3 and an unlocked SIM card.

**Step-by-Step Assembly Instructions:**

1. Insert an unlocked SIM card to the SIM cardholder of the GSM shield and assemble the GSM antenna.
2. For communication port configuration of the GSM shield, place the jumpers of digital pins receive ($R_XD$) and transmit ($T_XD$) to the position of 2 and 3. The position is highlighted in those yellow boxes shown in Figure 27.

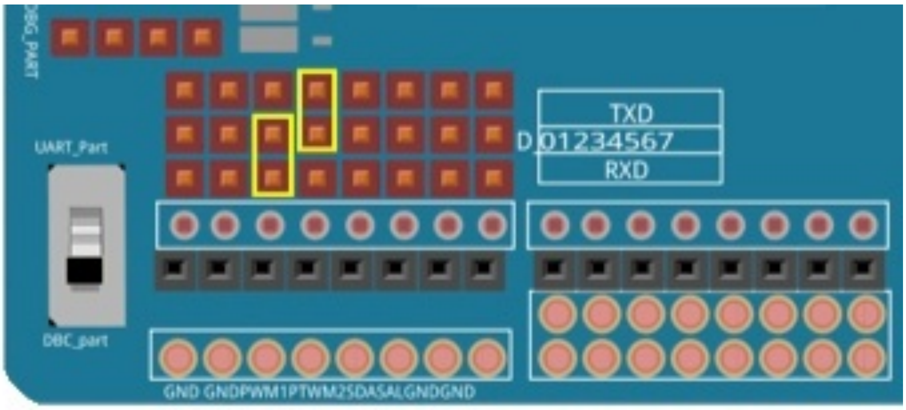



FIGURE 27. GSM Shield Software Serial Pins Positioning

3. Plug the GSM shield into Arduino UNO R3 socket as shown in Figure 28.

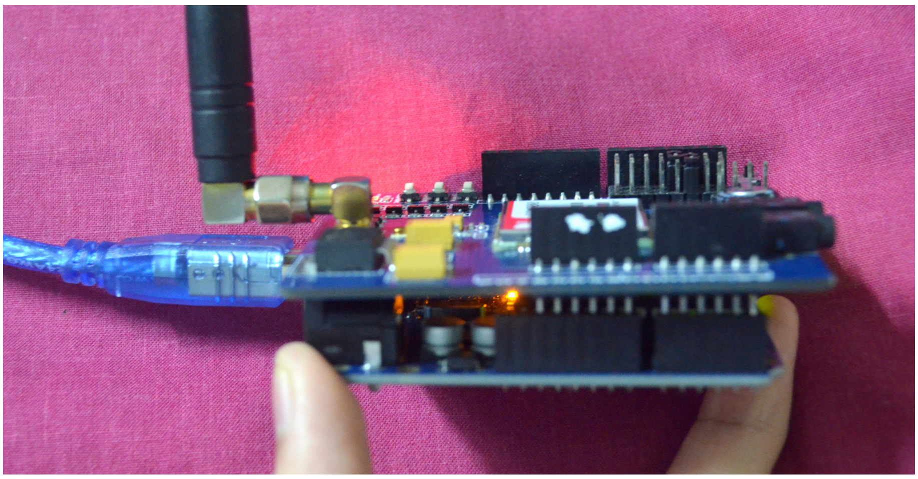


FIGURE 28. GSM Shield Attached on Top of Arduino

4. Upload a sketch that contains the instructions code to control the functionality of Arduino into the Arduino board.

### 5.3.2 Test 1: Accuracy Testing

**Objective**

The purpose of conducting this test is to determine the accuracy of data collected from the ultrasonic sensor. In this context, data refers to the distance measured in centimetres between the ultrasonic sensor and surface of water.

**Scope of Testing**

Ultrasonic sensor is initialized to use pin A2 for echo input and pin A3 for trigger output with a maximum ping distance of 200 cm. The accuracy of data collected from the ultrasonic sensor is determined by comparing its measurements with manual measurements using a 30 cm clear plastic straight centimeter ruler. Test is executed in an indoor environment with default setup shown in Figure 29.

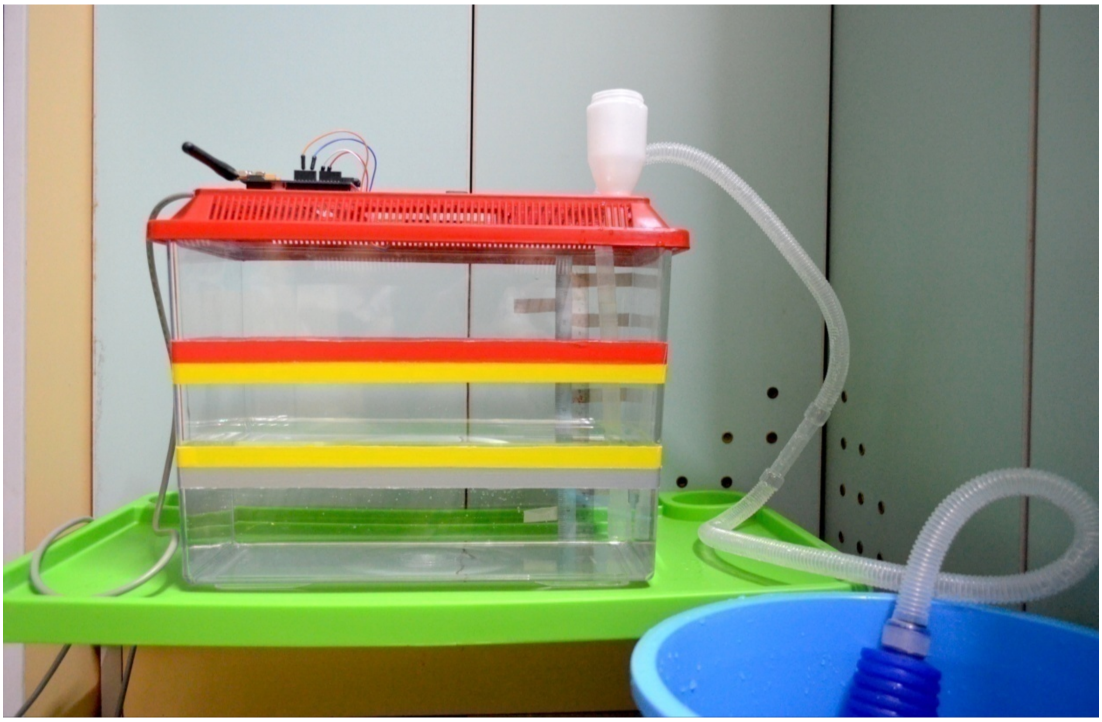


FIGURE 29. Default Experiment Setup

## Results and Discussion

According to the measurements recorded from the graph in Figure 30, out of the 30 trials that have been performed, it appears that the shortest distance measured by the sensor is 7 cm, while the actual distance recorded shows 7.2 cm.

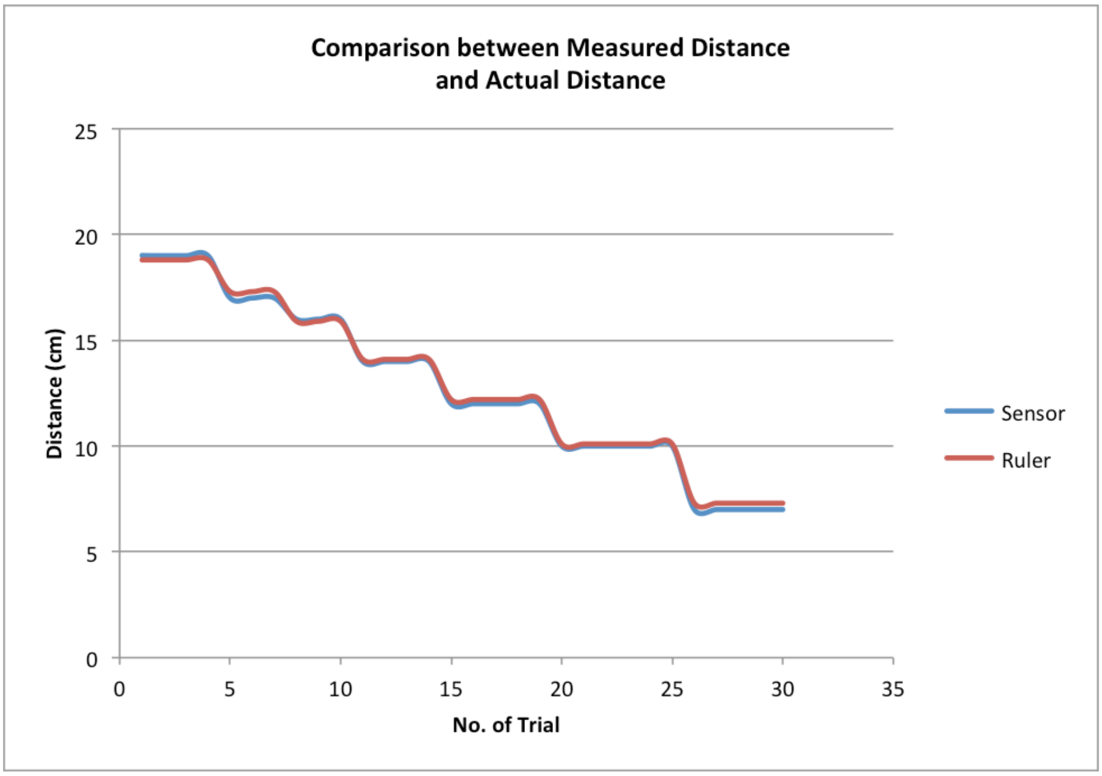



FIGURE 30. Comparison between Measured Distance and Actual Distance

Nevertheless, the line graph in Figure 30 shows not much gap between the reading recorded by the ultrasonic sensor and the ruler. This shows that the ultrasonic sensor is accurate as it always recorded distance within 1 cm.

Moreover, based on the bar graph shown in Figure 31, the average accuracy is calculated at over 93%.

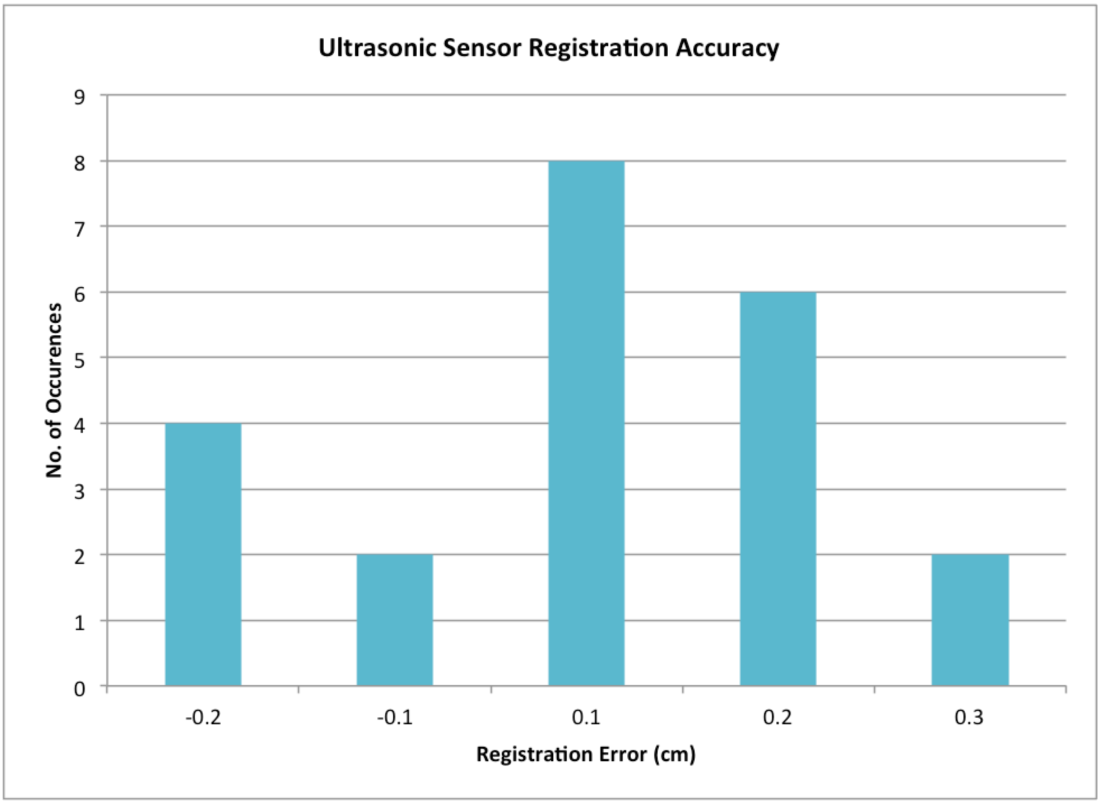



FIGURE 31. Ultrasonic Sensor Registration Accuracy

27% out of 93% has actually recorded 100% accurate measurement with less than 0.1 cm of error, which results in registration error percentage of 7%. However, these results are all within an acceptable precision range within ±0.2 cm.

**Conclusion**

Based on the results, data collected from the ultrasonic sensor is consistent throughout the number of trials. There is a very good correlation between the distance recorded by the ultrasonic sensor and the actual distance measured with a ruler. Therefore, it is safe to conclude that the ultrasonic sensor does provide accurate reading with 93% to 100% success rate. The objective of conducting the test is achieved.

### 5.3.3 Test 2: System Testing

**Objective**

The purpose of conducting this test is to calculate the average velocity of water rising. The velocity will be used to forecast a specific time frame to broadcast warning SMS to the victims. It is important to get good estimation on the time frame to ensure ample time is given to the victims to evacuate the event area before the flood becomes worse.

**Scope of Testing**

Test 2 is performed in an indoor environment as shown in Figure 32 for 37 minutes and 59 seconds. In order to calculate the velocity of water rising, the aquarium tank is set to receive free flow of water coming in and out from the tank. The time delay to retrieve new data from the ultrasonic sensor is set to an interval of 30 seconds.

FIGURE 32. Experiment Setup with Free Flow of Water Inlet and Outlet

**Results and Discussion**

Table 6 shows a list of value gathered from the experiment, in which the value represents the following parameter. The value is used to calculate the average velocity of water rising.

TABLE 6. Value Recorded from Test 2: System Testing

| di | df | Δd (m) | ti | tf | Δt (s) | v(av) = Δd / Δt (ms) |
|---|---|---|---|---|---|---|
| 0.23 | 0.19 | - 0.04 | 592 | 657 | 65 | - 6.15 |
| 0.19 | 0.17 | - 0.02 | 787 | 852 | 65 | - 3.08 |
| 0.19 | 0.17 | - 0.02 | 852 | 917 | 65 | - 3.08 |
| 0.17 | 0.15 | - 0.02 | 986 | 1047 | 61 | - 3.28 |
| 0.17 | 0.16 | - 0.01 | 1047 | 1112 | 65 | - 1.54 |
| 0.15 | 0.16 | 0.01 | 1112 | 1177 | 65 | 1.54 |
| 0.16 | 0.14 | - 0.02 | 1177 | 1242 | 65 | - 3.08 |
| 0.16 | 0.14 | - 0.02 | 1242 | 1311 | 69 | - 2.90 |
| 0.14 | 0.12 | - 0.02 | 1437 | 1502 | 65 | - 3.08 |
| 0.14 | 0.12 | - 0.02 | 1502 | 1567 | 65 | - 3.08 |
| 0.12 | 0.1 | - 0.02 | 1762 | 1827 | 65 | - 3.08 |
| 0.12 | 0.1 | - 0.02 | 1827 | 1902 | 75 | - 2.67 |
| 0.1 | 0.07 | - 0.03 | 2152 | 2217 | 65 | - 4.62 |
| 0.1 | 0.07 | - 0.03 | 2217 | 2285 | 68 | - 4.41 |
| 0.07 | 0.05 | - 0.02 | 2477 | 2542 | 65 | - 3.08 |

**Legend:**

di: Initial Distance of Water Surface to Ultrasonic Sensor in Metres

df: Final Distance of Water Surface to Ultrasonic Sensor in Metres

Δd: Change in Distance in Metres

ti: Initial Time of Water Rising in Seconds

tf: Final Time of Water Rising in Seconds

Δt: Change in Time in Seconds

v(av): Change in Water Rising Velocity in Metres per Seconds

From the calculation of change in water rising velocity from Table 6, a velocity against time graph is plotted as shown in Figure 33.

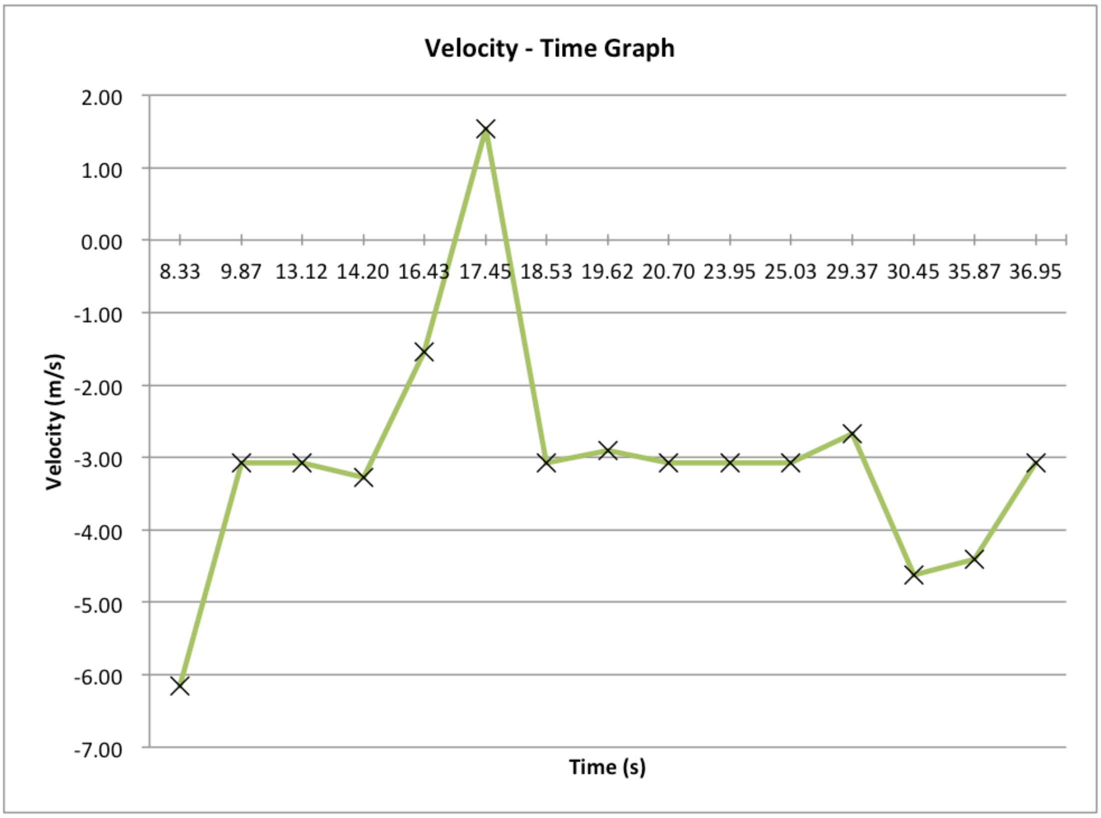



FIGURE 33. Velocity against Time Graph

The graph shows negative velocity, which means the water level is moving backwards in a negative direction. This indicates that water keeps rising towards the ultrasonic sensor. However, there was one time where water level is recorded to be reducing, hence the positive velocity. This may have happened due to water level that changes rapidly as water is flowing in and out almost simultaneously from the aquarium tank.

**Conclusion**

Based on the results, the changes in water rising shows negative velocity, which implies that the water level is moving towards the ultrasonic sensor as water level increases. During the event of flooding, water level in the river changes quickly and thus, warning SMS need to be delivered early to the victims. This is to ensure ample time is given for them to evacuate the event area before the flood becomes worse.

### 5.3.4 Test 3: Performance Testing

**Objective**

The purpose of conducting this test is to check the stability and reliability of the pre-flood warning system. This is done to ensure the system can perform well in measuring water level accurately as well as sending warning SMS immediately.

**Scope of Testing**

Test is executed in an outdoor environment with water flowing in and out from the aquarium tank almost simultaneously. Similar setup to the setup of experiment in Test 2 is used.

**Results and Discussion**

The reliability of the system is measured by comparing the number of serial monitor displaying SMS status *Sent* with the number of SMS that is actually received by the recipients. The stability of the system is measured by looking at the consistency of data collected by the ultrasonic sensor.

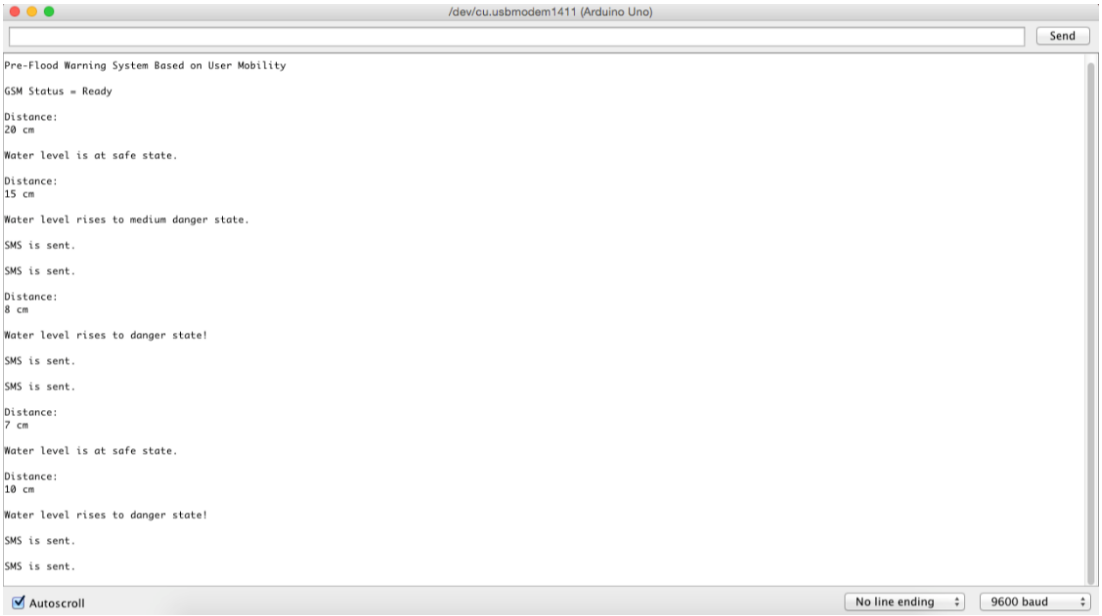



FIGURE 34. Output Displayed on Serial Monitor

Output displayed on serial monitor in Figure 34 matches the number of warning SMS delivered to recipients' mobile phone as shown in Figure 35.

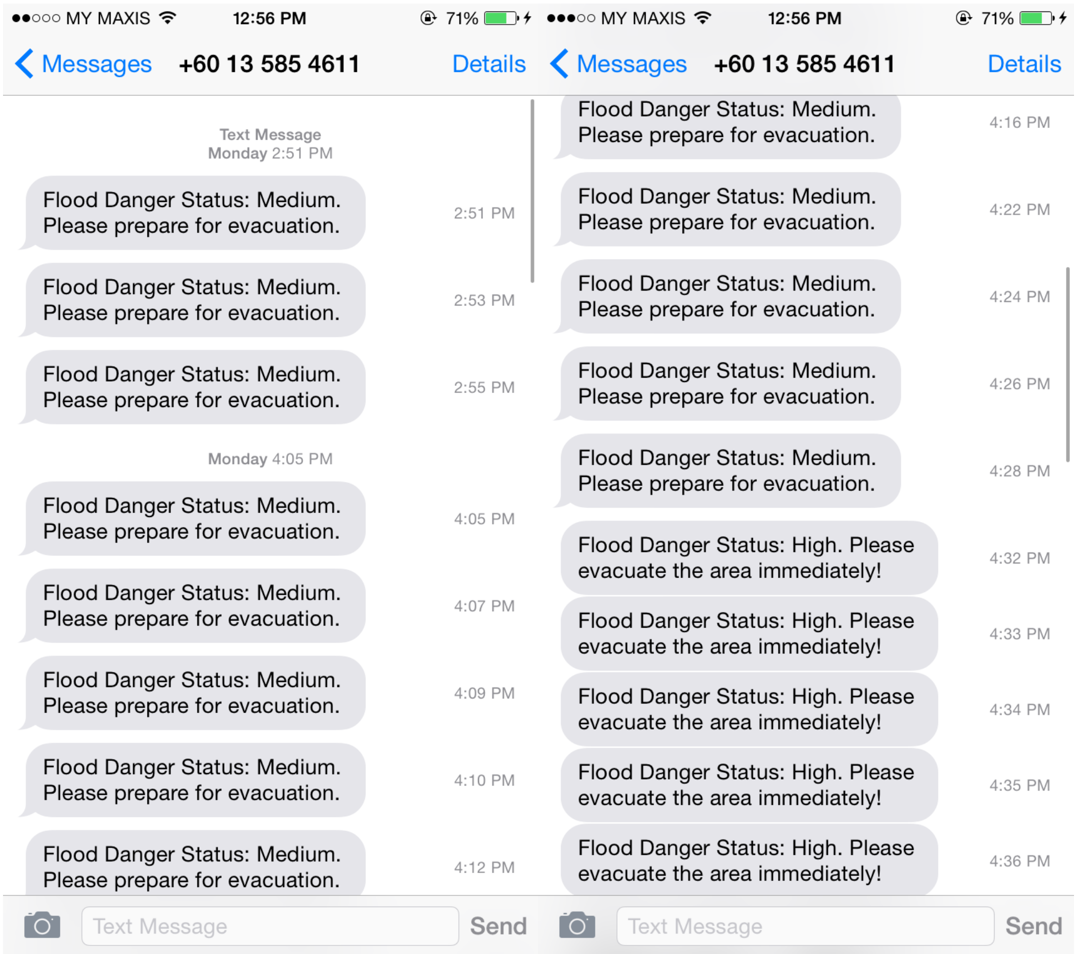



FIGURE 35. Actual SMS Delivered to Recipients' Mobile Phone

However, during the first test, out of 30 trials, two (2) warning SMS actually failed to reach the recipients but the status on serial monitor displayed it as *Sent*. This may have happened due to network congestion or other factor that affects the performance of the GSM shield in broadcasting warning SMS. Nevertheless, the second test is completed and the result is summarized in a line graph shown in Figure 36.

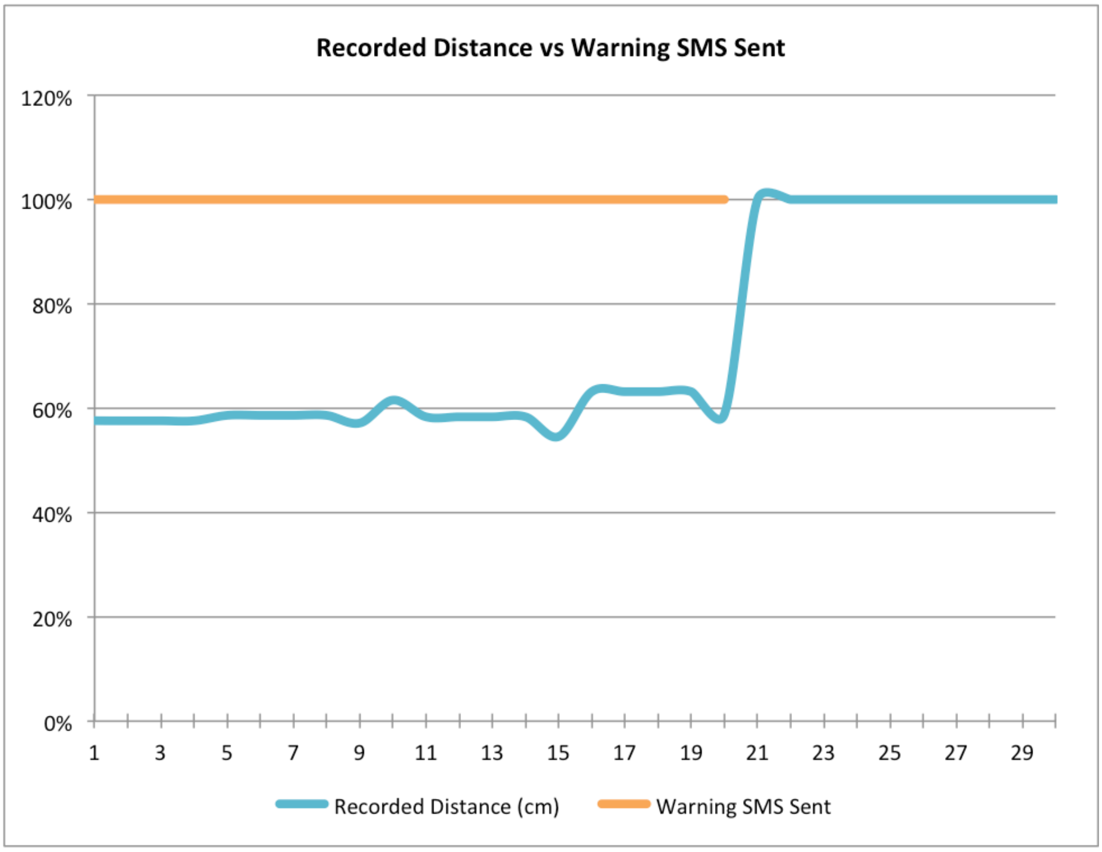



FIGURE 36. Recorded Distance against Warning SMS Sent

From the graph in Figure 36, the system has managed to broadcast warning SMS for all recorded water level status of medium and high, with 100% success rate. The reading of water level collected by the ultrasonic sensor is also consistent until the water subsided to extremely low level.

### Conclusion

Based on the results, the system is already stable in recording water level distance accurately. The system is also reliable as it is able to broadcast warning SMS as soon as water level increases to the medium and high danger phase.

## 5.4 Problems Encountered and Solutions to Overcome

### 5.4.1 Establishing Connection between GSM Shield and Arduino

There were several problems encountered throughout completing the prototype development of the pre-flood warning system. The first problem that took so much time to resolve is to establish connection between IComsat GSM shield serial software pins with the communication port of Arduino board. A lot of effort was put in to verify this error such as: the programming source code has been verified and there was no error, the required GSM library has been installed, the SIM card was unlocked, activated and inserted correctly. Despite all these effort, the GSM shield still fails to send SMS.

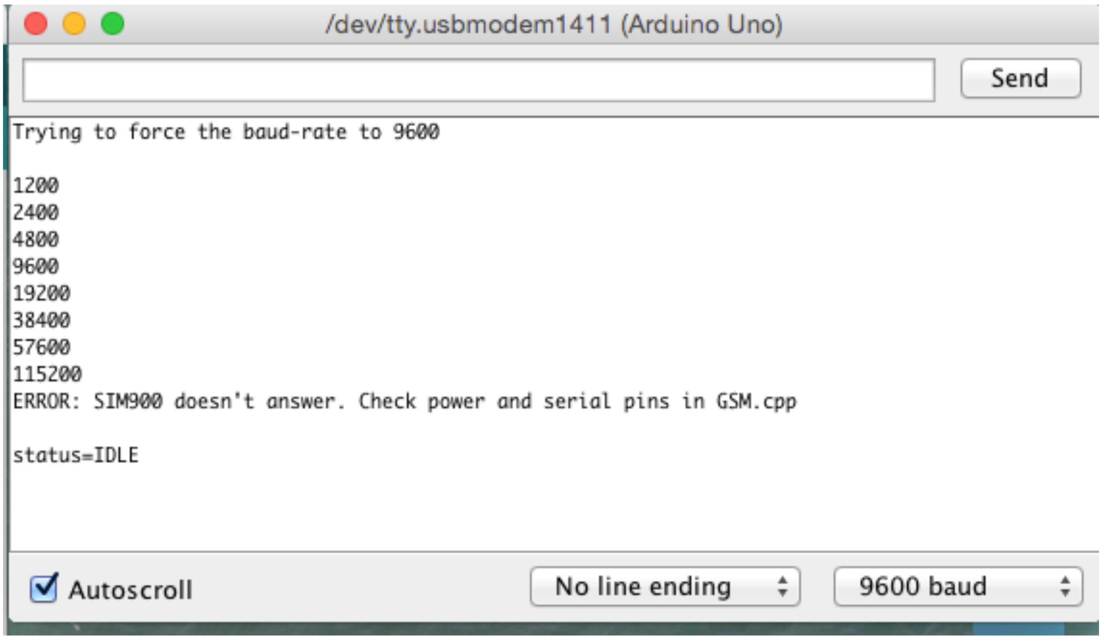



FIGURE 37. Error Message When GSM Shield Failed to Establish Connection

Figure 37 shows the error message received from the IDE. Several approaches have been carried out to counter this problem: the first attempt was to use a 12V 1A power adaptor to supply power to both Arduino and GSM shield, but the GSM shield remains idle. Secondly, the serial pins in GSM.cpp were updated but there was no part in the source code that loads GSM.cpp, thus changing it was useless. The final attempt has successfully solved this problem. The jumpers on the GSM shield that were initially set as default at D0, D1, were moved to D2, D3.

### 5.4.2 Ultrasonic Sensor Failed to Communicate with Arduino

The second problem happened when ultrasonic sensor fails to connect to Arduino. When these two components failed to communicate with each other, the sensor is recording no value. Fortunately, reconnecting these two components using new jumper wire resolved this problem.

### 5.4.3 Integration of Solar Panel with Arduino

The third and final problem happened during the final stage of development for the prototype model. Initially, solar panel was included in the proposed system architecture as main supply of power to this system considering that electricity supply will be cut off during the event of flooding. However, the solar panel had to be removed and a thorough investigation and exploration work is needed to figure out how to integrate the solar panel to the Arduino board.

# CHAPTER 6
# CONCLUSION AND RECOMMENDATION

## 6.1 Conclusion

The three main objective of the project have been successfully met.

A small-scale study of flood disaster in Kelantan, Terengganu, Pahang, Perak and Johor has been conducted. The study aims to gather information regarding the number of displaced population during the event of flooding and to get an overview on the aftermath of floods. A successful analysis of comparative study on the existing work has been finalized and a critical analysis between the available technologies has been conducted based on the gaps identified in the literature. By doing this, the first objective has been achieved, which is to perform a comparative study of flood disaster in Malaysia and the existing pre-flood warning tools.

A prototype system that detects three (3) stages of water level (i.e. high, medium and low) and broadcasts warning SMS immediately has been successfully developed. The prototype model is made up of a medium sized plastic aquarium with a hand pump to allow water to be pumped in and out of the aquarium tank. Hardware components that include ultrasonic sensor HC-SR04, a 5.5 cm x 8.5 cm breadboard, IComsat GSM shield and GSM antenna, Arduino UNO R3 and an unlocked SIM card, have been setup. The step-by-step assembly instructions for the components have been reported clearly in Chapter 5. The programming of the source code has been explained and and the integration between hardware and software component has been detailed out thoroughly. Therefore the second objective, which is to develop a prototype system for the proposed pre-flood warning system is accomplished.

Successful development of the prototype system is then validated with three (3) tests, namely accuracy testing, performance testing and system testing. These tests have been conducted to ensure that the system is able to measure water level accurately and to prove that the system is reliable to broadcast warning SMS as soon as the water level condition (i.e. high and medium) is met based on the threshold initialized in the source code. The results from the experiment conducted show that the proposed prototype system is working as intended and with 96% to 100% success rate; the ultrasonic sensor is proven to be able to measure water level accurately. Consequently, the third objective of validating the prototype system through experimentation is met.

In conclusion, the development of the pre-flood warning system was a success even though the solar panel is not included in the prototype system. However in real implementation, the solar panel will be added to ensure the system is working when electricity supply is being cut off. Moreover, by having an effective pre-flood warning system, immediate action can be carried out by the local authorities, which will accelerate the process of evacuating flood victims to the relief center. Thus, millions of Ringgit in damage can be reduced along with the loss of life and property as well as the devastation of agricultural and livestock.

This work has been presented in the International Symposium on Mathematical Sciences and Computing 2015 Conference. It is currently in-print in the IEEE Xplore® and is indexed by Scopus.

## 6.2 Recommendation

This project has great potential to be extended encompassing much functionality. Therefore, several recommendations need to be highlighted for those who are interested to continue this project.

### 6.2.1 Add Solar Panel as Main Power Supply

Based on the small-scale study of flood disaster shown in Chapter 2, the electricity supply had to be cut off during the occurrence of flood to avoid the victims from being electrocuted. Thus, solar panel is required to give electricity supply to ensure the system works even though the electricity is not available. It is recommended to use a 12 volts and 4 watts polycrystalline solar panel as it produces more power to charge batteries. It is also more sensitive towards light, which enables fast charging.

### 6.2.2 Implement Artificial Intelligence Concept or Expert System

For the time being, the system is not equipped with any Artificial Intelligence concept or Expert System such as fuzzy logic. By having a fuzzy logic expert system model, the system will acquire the capability of self-learning and forecasting. With uncertain weather conditions, this concept will be able to accurately predict the flood risk level based on the water level measured by the ultrasonic sensor.

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# APPENDICES